



TRANSPORTATION-  
MARKINGS: A  
HISTORICAL SURVEY,  
1750-2000

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A STUDY IN COMMUNICATION  
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TRANSPORTATION-  
MARKINGS:  
  
A HISTORICAL SURVEY,  
  
1750-2000

Part J Volume IV, Final Studies

Transportation-Markings: A Study in  
Communication Monograph Series

Brian Clearman

Mount Angel Abbey 2002

Dedicated to the Memory of  
 Abbot Anselm Galvin, OSB  
 (1916--1994)

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## PREFACE

Diverse Transportation-Markings forms can be extracted from their original "home" (road, rail, marine, aero) and reconstructed as an integrated message system within an abstract construction (via semiotics/communications). But for this historical survey that method has not been followed. A history requires retention of the original character, its coloring, its shape. And a history that surveys diverse forms and modes can lead to a clash of cultures. The core message character remains and is shared among the various forms, but the original context of the messages is much less easily shared and an apparent disjunction can result.

For example, describing historic lighthouses takes on the coloring -- even mores -- of the Victorian era. It also includes the developing civil engineering profession as applied to maritime needs. The scientific and technological developments of the time are also present. Even writers who write about lighthouses shape the sense of those long long ago aids. But describing the beginnings of satellite navigation (and we are not far from those beginnings) and a different scenario emerges: sophisticated engineering and technology, divergent energy forms, a different mindset and attitudes of those designing, constructing, launching satellites as well as those creating the actual navigation aids. But if one strains out the particulars leaving only the universal then much is lost.

This monograph has therefore an uneven quality about it; even a clash of styles in materials and sources; the juxtaposition of old and new; of traditional and contemporary mindsets. If unsuccessful it may be because of those reasons. However, a blending of forms and resources into a seamless, smooth entity might be more pleasing but it could not be viewed as successful either.

\* \* \*

A reading of this monograph may suggest an attachment to old and traditional aids (especially traditional lighthouses) by the writer, and simultaneously a disparagement of radio aids. The situation is not nearly that simple. Safety in navigation has changed dramatically in the past 250 years and especially in the 20th century. It is unlikely those changes can be undone, or that most people would even attempt such a reversal. But a result of those changes suggests the growing possibility of a monoculture that centers on electronics -- and in particular on GPS -- and a sloughing off of visual, acoustic and even older electronic forms. Such a focus on a single kind of safety aid is not necessarily an unmitigated blessing. Removing the visual part of safety aids (and to some degree, the acoustical) creates a worrisome situation. This is not to suggest a monoculture of a visual form would be acceptable while an electronic one is not. A visual/acoustical monoculture once did exist.

A ship sailing from New York to London in the late 19th century would lack the electronic systems now taken for granted. And that would include electronic systems both within and without the vessel. The skills and wits of captain and crew coupled with traditional means of navigation would be the total "package" of methods and means of sailing from one port to another. Not infrequently a violent storm in the North Atlantic would throw a ship off course so that captain and crew were uncertain as to location. It would also reduce the possibility of regaining a clear sense of location. No GPS, Loran, Decca, Consol, Radio Beacons were available; no radio, not even a cell phone. If the ship more or less found its way and was somewhere near the approaches to Ireland and England it might be seen as nearly home free: the great lights of Eddystone, Scilly Isles, the Lizard could guide the battered vessel to its home port. However, if the ship exchanged the storm for a pea soup fog then what? Position already uncertain, landmarks obscured, and the lighthouses blinded. By straining their collective ear the captain crew might in time hear a explosive charge set off at a rock lighthouses. Or they might hear the roar of the sirens at the Lizard atop the

Cornwall cliffs. But sound propagation in air is an uncertain business. Sound can carry well but sound can also be muffled and heard for no great distance. Fog can alter fog signals all too well. The voyage might end successfully. But it was a uncertain and high risk adventure from start to finish. Few mariners would voluntarily return to those days. Electronic aids have become a welcome and vital component of safety.

But depending on any one kind of safety device -- no matter what kind -- is fraught with risk. The breakdown of electronic communications has already occurred on a major scale. Some years a critical communication satellite simply stopped working without warning. A vast number of pagers and beepers became unusable. That is a blessing from some viewpoints. Yet many health care people were dependent on that one satellite. Its shutdown became literally life-threatening. Without warning alternate ways of communication had to be cobbled together. Technological breakdowns, atmospheric conditions, malfunctions of receiving equipment can all impair electronic aids. A monoculture of whatever form is potentially a high risk. This study does not question the value of electronics but it questions the move toward a dominance by electronics.

\* \* \*

Even if the study is not seen as a disparagement of electronics it might be observed that this book over-emphasizes the visual. Yet the visual, and acoustical, have been around for a very long time. It seemed valid to demonstrate the value of traditional visual and acoustical transportation-markings in this study. But at the same time the study notes the decline of many of those forms, and the increase in electronic forms. A study at the end of the 21st century no doubt would give electronic forms much more attention and other forms less so. And an additional quarter-millennium might do so to a much greater extent. But this study has much to do with what can be seen and heard directly and immediately. Hopefully future studies by others will also record a robust visual/acoustical dimension to safety aids no matter how great a role the electronic may

have assumed.

\* \* \*

There are three principles of organization in Part J:

1) The form of message is the first principle: visual, electronic or acoustic. Many of the T-M studies are arranged by transportation mode but in this more integrative account the form of message (which cross modal boundaries) takes precedence.

2) Chronology may logically appear to be the basic principle yet that arrangement would necessarily have to include both message forms and modes within chronology (within each chapter all forms of message and all modes of transportation would have to be included). While that would create a more integrative approach on one level it would also separate related forms. In addition the chronology for one form may not fit the chronology of another form. The simpler approach of starting with type of message then moving to chronology has therefore been adopted.

3) Finally, modes of transportation provide a tertiary principle for the arrangement of (for example, aero and marine forms are elements within radio aids).

The character of T-M for the past 250 years is shaped, influenced by developments in science and technology. The Industrial Revolution(s) is therefore a pivotal event for Transportation-Markings. The Industrial Revolution(s) is surveyed in the first chapter. That survey, though not exhaustive, provides a necessary context, backdrop for T-M.

\* \* \*

This study is divided into five chapters. Chapter 1, Prelude to Modern T-M History, introduces the monograph, presents a survey of pre-1750 T-M forms, and ends with an overview of the Industrial Revolution.

Visual Transportation-Markings is the most long-enduring dimension of T-M from ancient times to the present. The extensive nature of those forms requires two chapters:

Chapter 2, Visual I, covers 1750 to 1920. There are three phases within that time: 1750-1820 which is a period of relatively primitive aids in which technological changes is in an early state. 1821-1870 marks a more modern time in which aids are more diverse and numerous and more affected by technology. 1871-1920 marks the apex of visual aids. The zenith of grand coastal lighthouses -- with their giant lanterns and beams stretching to the horizon -- occurs after 1870. Radio is, at most, a minor element in that time and hence the visual dominates as it would not after 1920. Railway semaphore signals, with their two-part character, undergo much of their mature development during that phase though the seeds of their decline are also found in that era. The beginnings of all-lighted signals (which are the "seeds" of the decline of the semaphore) are also to be found in that time. The very earliest aero aids begin to appear with a hint of future development. Traffic signals are also contained in this era; signals begin to take on their modern shape though they are still in a relatively embryonic state.

Chapter 3, Visual Aids II, 1920-2000 encompasses two phases: the first three decades in which traffic signals take on their contemporary appearance. Many forms of aero aids have begun and they also undergo much of their eventual form from edge lights to approach lighting. Marine lighting undergoes technical advances though radio gains in importance at the expense of visual forms. Railway signals take on their substantially modern appearance and all lighted versions begin to dominate. The second phase, the last fifty years, is marked by some advances in visual aids though radio forms move toward some measure of dominance so that the visual is in a relative decline though stable in some respects.

Chapter 4, Radio Aids, 1904-2000 includes two phases.

The first begins early in the 20th century and ends about the time of World War II. The second phase begins with the war years and continues for the remainder of the century. During World War II an enormous expansion of radio aids occurred that would continue on at an accelerating rate. Late in the 20th century a single aid, GPS, threatened (or promised) not only to eclipse but replace many T-M forms no matter their nature: visual, acoustical or even electronic.

Chapter 5, Acoustical Aids, covers 1750 to 2000. It is a numerically small unit yet it has had a significant role in a variety of settings. Mostly known for marine fog signals there have been sound signals for road and rail, and even aero has included sound indications of a sort.

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## ABBREVIATIONS

### Authors, and Publications

|          |                                |
|----------|--------------------------------|
| AAR 1949 | Association of American ....   |
| AAR 1987 | " " "                          |
| AAR 1953 | " " "                          |
| AC       | <i>American City</i>           |
| AD       | Aerodromes: ICAO               |
| AI       | <i>Airports International</i>  |
| AIP      | Aeronautical ...: U.S. FAA     |
| AT       | Aero. Telecommunications: ICAO |
| AW       | <i>Aviation Week</i>           |

|               |                                            |
|---------------|--------------------------------------------|
| B & M         | Brigano & McCullough                       |
| UTCDC         | Uniform TCD ... Canada                     |
| CE            | <i>Collier's Encyclopedia</i>              |
| CGAN 1977     | U.S. Coast Guard <i>Aids ...</i>           |
| CRICMV        | Convention with Respect ...                |
| CSM           | <i>Christian Science Monitor</i>           |
| EA            | <i>Encyclopedia Americana</i>              |
| EB            | <i>Encyclopedia Britannica</i>             |
| TE            | <i>Traffic Engineering</i>                 |
| ERCR-RSS      | European Conference of Ministers ...       |
| ERS           | <i>European Railway Signaling</i>          |
| Extracts 1861 | U.K. Royal Commission on Lights ...        |
| F & D         | Forbes & Dijksterhuis                      |
| FRP           | Federal Radonavigation Plan                |
| G & L         | Grotterod & Liavaag <i>TE</i>              |
| H & C         | Hague and Christie                         |
| H & W         | <i>Horn &amp; Whistle</i>                  |
| IAMM          | <i>Inter-American Manual</i>               |
| ICRMT         | International Convention ... Motor T ...   |
| ICRMV         | International Convention ... Motor V ...   |
| IDAMN         | IALA, <i>International Dictionary ...</i>  |
| IHR           | <i>International Hydrographic Review</i>   |
| IJ            | <i>ICAO Journal</i>                        |
| Jer           | Biblical Book of Jeremiah                  |
| JN            | <i>Journal of Navigation</i>               |
| K & W         | Kitchenside & Williams                     |
| La & Wa       | Last & Ward                                |
| Le & We       | Leffingwell & Welty                        |
| LD            | <i>Literary Digest</i>                     |
| LLPCPI        | U.S. Coast Guard, <i>Light List ...</i>    |
| LN CCURS      | League of Nations, Convention              |
| LN OCT-CERCL  | League of Nations, Organization            |
| LN ECRT       | League of Nations, European                |
| LN TS         | League of Nations-Treaty Series            |
| McG H EST     | McGraw-Hill Encyclopedia S & T             |
| MUTCD         | <i>Manual on Uniform TCD</i>               |
| NH            | <i>Natural History</i>                     |
| NJIN          | <i>Navigation: The Journal of ...</i>      |
| NYT           | <i>New York Times Magazine</i>             |
| OIFWH         | <i>Oxford Illustrated Encyclopedia ...</i> |
| PICHSS        | <i>Proceedings ... Symbology</i>           |
| RG 1873, 1884 | <i>Railroad Gazette</i>                    |

|              |                                                 |
|--------------|-------------------------------------------------|
| RH           | <i>Random House College Dictionary</i>          |
| RHDEL        | <i>Random House Dictionary English ...</i>      |
| REAMC        | <i>Railway Engineering &amp; Maintenance ..</i> |
| RSD          | <i>Railway Signal Dictionary</i>                |
| SA TWR       | <i>South Africa Train Working</i>               |
| S & B        | <i>Simmons &amp; Biddle</i>                     |
| Starkey HDS  | <i>Starkey, History &amp; Development ...</i>   |
| UK HADTS     | <i>U.K. History &amp; Development ...</i>       |
| UN CORSS     | <i>U.N. Convention on ...</i>                   |
| UN DCRSS     | <i>U.N. Draft Convention</i>                    |
| UN DCRSS-NSG | <i>U.N. Draft Convention-Note</i>               |
| UN ECE       | <i>U.N. Economic Commission Europe</i>          |
| UN RSG       | <i>U.N. Report- Secretary-General</i>           |
| UN SR        | <i>U.N. Summary Reports</i>                     |
| WNID         | <i>Webster's New Int'l Dictionary</i>           |
| WSJ          | <i>Wall Street Journal</i>                      |

#### Organizations

|        |                                           |
|--------|-------------------------------------------|
| AASHO  | American Association State ...            |
| AGA    | American Gas Accumular                    |
| AIARC  | Association Int'l Automobile Clubs.       |
| ALPA   | Airline Pilots Association                |
| ANC    | Army Naval Civil Committee                |
| ATA    | Airline Transport Assn CHECK              |
| AWOP   | ICAO- All Weather Ops Panel               |
| B & O  | Baltimore & Ohio RR                       |
| CAA    | Civil Aviation Authority                  |
| CASATC | Central & Southern Africa Tr Conf         |
| CIE    | Commission Internationale de l' Eclairage |
| DMA    | Defense Mapping Agency                    |
| DOT    | Dept of Transportation                    |
| EC     | European Conference... Transport          |
| ECAFE  | U.N. Economic Council for Asia ...        |
| ESCAP  | U.N. Economic & Social Council            |
| FAA    | Federal Aviation Agency                   |
| FRA    | Federal Railroad Administration           |
| GERSS  | U.N. Group of Experts Road ...            |
| GRS    | General Railway Signal                    |
| HR     | U.S. House of Representatives             |

|         |                                    |
|---------|------------------------------------|
| IALA    | Int'l Assn Lighthouse Authorities  |
| IATA    | Int'l Airtransport Assn            |
| ICAO    | Int'l Civil Aviation Organization  |
| IEEE    | Instit. of Electronic & Electroni  |
| IMCO    | Inter-maritime Consultative Organ. |
| IHB     | Int'l Hydrographic Bureau          |
| IRSE    | Institution of Railway Signal Est. |
| ITD     | Int'l Telegraph Development Co.    |
| IUR     | Int'l Union of Railways (also UIC) |
| L-M     | Line-Material Co.                  |
| MVASHD  | Mississippi Valley ... State Hghwy |
| NAS     | National Academy of Sciences       |
| NCSHS   | Nat Conf. State & Highway Safety   |
| NGS     | National Geography Society         |
| ORE-UIC | Office of Research ... -IUR/UIC    |
| PAHC    | Pan American Highway Congress      |
| PIARC   | Permanent Int'l Assn of Road Con   |
| PICAO   | Provisional ICAO                   |
| RAE     | Royal Aerospace Establishment      |
| RAF     | Royal Air Force                    |
| RSA     | Railway Signal Association         |
| RTCA    | Radio Technical Commission         |
| UIC     | Union Int'l des Chemins, also      |
| UK MOT  | UK Ministry of Transport           |
| UN      | United Nations                     |
| URO     | United Railway Organization        |
| US ICC  | U.S. Interstate Commerce Com.      |
| USAF    | U.S. Air Force                     |
| USCG    | U.S. Coast Guard                   |
| USLHE   | U.S. Lighthouse Establishment      |
| USNOO   | U.S. Naval Oceanographic Office    |
| WBAS    | Westinghouse Brake & Signal        |
| WRSC    | Western Railroad Supply Co.        |

#### Technical Terms

|     |                                |
|-----|--------------------------------|
| ASV | Detection ... Surface Vehicles |
| CTC | Central Traffic Control        |
| FM  | Frequency Modulation           |
| FOC | Full Operation Capacity        |
| HF  | High Frequency                 |

|     |                                 |
|-----|---------------------------------|
| IFF | Identification of Friend or Foe |
| KHz | Kilohertz                       |
| LF  | Low Frequency                   |
| LOP | Line of Position                |
| LQ  | Lower Quadrant                  |
| M   | Meter                           |
| MHz | Megahertz                       |
| MF  | Medium Frequency                |
| ATC | Automatic Train Control         |
| UQ  | Upper Quadrant                  |
| VHF | Very High Frequency             |

#### T-M Terms

|           |                                 |
|-----------|---------------------------------|
| A/N       | Aids to Navigation              |
| ASR       | Airport Surveillance Radar      |
| DGPS      | Differential GPS                |
| DME       | Distance Measuring Equipment    |
| DMLS      | Doppler MLS                     |
| DNSS      | Defense Navigation Sat. System  |
| GCA       | Ground Control Approach         |
| GNSS      | Global Navigation Sat System    |
| HAPI      | Helicopter Ap Position Ind      |
| ILS       | Instrument Landing System       |
| ILWS      | Inductive Loop Warn. System     |
| LH        | Lighthouse                      |
| LS        | Lightship                       |
| MLS       | Microwave Landing System        |
| Navstar   | Nav Sys with Timing & Ranging   |
| NDB       | Non-Directional Beacon          |
| NTS       | Navigation Technical Satellite  |
| OBS       | Old British System              |
| OM        | Outer Marker                    |
| PAPI      | Precision Ap Path Indicator     |
| PAR       | Precision Approach Radar        |
| PLASI     | Pulse Light Ap Slope Indicator  |
| POPI      | Post Office Precision Indicator |
| QM        | Early name for Decca            |
| RDF       | Radio Direction Finder          |
| R-W VASIS | Red White VASIS                 |
| SEL       | Lorenz Co.                      |

|          |                            |
|----------|----------------------------|
| SBA      | Standard Beam Approach     |
| SS Loran | Sky-Synchronized Loran     |
| TACAN    | Tactical Air Navigation    |
| TCD      | Traffic Control Devices    |
| TOWS     | Train Op Warning System    |
| TRSB     | Time-Reference Scan. Beam  |
| T-VASIS  | Tee-VASIS                  |
| VASIS    | Visual Ap Slope Ind System |
| VHF/BA   | VHF Beam Approach System   |
| VOR      | VHF Omnidirectional Range  |
| VORTAC   | VOR and TACAN              |

## CHAPTER ONE

### PRELUDE TO MODERN TRANSPORTATION-MARKING HISTORY

#### 1A Early History of Transportation-Markings

##### 1A1 Survey of T-M Before 1750: Marine Aids

A survey of newer T-M forms can be a reasonably precise and accurate exercise. Government regulations, international systems of T-M, manufacturers' catalogues, anecdotal articles and books, diverse and numerous documents all provide data for such a survey. However, older T-M forms are often local installations with only limited documentation. Writers on older lighthouses, buoys, beacons, fog signals, road marks often speak only briefly – and imprecisely – of older forms (with the partial exception of lighthouses). An account of T-M forms before 1750 is therefore a less than certain or complete enterprise. Nonetheless, a sketch of older aid forms remains possible.

Fog Signals were in use before the mid-18th century. Early fog signals included rockets, cannons, bells and gongs. However, a variety of references to such aids in the literature lack specificity. For example, Talbot at one point speaks of "early days" which is certainly lacking in precision. (Talbot 1913, 13).

Wheeler 1990 notes that rockets and cannons were developed in the 18th century in Europe. (Wheeler 1990, 21). Fog cannon were employed in the U.S. beginning in the early 18th century (Adamson 1955, 363). Cannons have a long history and employment as a fog signal before the 18th century is possible.

Since bells date back to early Christian centuries their early usage as fog bells is plausible. Southey's poem, "The Inchcape Rock" (Bell Rock) relates a possibly legendary tale of a bell employed as a signal (possibly the 14th century) (Corbin 1926, 109; Beaver 1973, 45). References to employment of bells and gongs "in the early days"

provide few clues as to when they were employed. (Bowen 1947, 30). Talbot's catch-all term of "early days" referring to gun signals and bells has the same problem. Both bells and gongs may have predated explosive signals. (EB 1972, 1138).

Buoys existed long before mid-18th, even in medieval times. Naish, for example, presents evidence of buoys in 13th century Spain and 14th century Netherlands. Most buoys seemingly were of a barrel construction or "air-containing barrel buoys" in Naish's term. (Naish 1985, 51, 57). Some use of iron was involved in buoy construction in 16th century in England. Spar buoys have been a common form of buoy even if not known by that term for older forms. Spars (floating beams for Naish) manifested a major drawback by becoming water logged and eventually sinking. The employment of buoys and their installation was greatly altered with the availability of iron for all-metal buoys as well as for the means of laying buoys. (Naish 1985, 51).

Lightships may suggest a somewhat modern aid because of technical requirements yet such vessels were employed in the early 18th century. Possibly the oldest is the Nore lightship in England in the 1730s. It was a sailing ship, very primitive, displaying a group of candles affixed to a masthead. A dim light to be sure but it existed at a time when few lights of whatever character or intensity were available. (Bowen 1947, 30).

Fixed unlighted aids are a long-enduring form of aid because of the ease of construction. However terms for those aids can be a confusing and uncertain matter. Hague and Christie employ beacon though noting it can have two different meanings: a navigation mark or sign, or a notable hill employed for signal fires. (H & C 1975, 206). Unlighted beacons and daybeacons are additional terms employed by some sources. The T-M Database discusses these and other terms (including the French Balise and the German Bake) (T-M Database: Marine li).

Beacon in some form date back a thousand years or

more. (Naish 1985, 37-38). Such aids might take the form of a human-assembled construction (such as a tripod) or of a natural form. Trees and tree branches stuck in mud banks denoting channel edges were typical natural aids. These forms continued in use even as other forms of beacons were introduced before the early modern era. Naish notes that many changes occurred in the 16th and 17th century because of increased sea trade and the reduction of piracy. New forms often consisted of timbered beacons and beacon towers. In time beacons developed into more complex designs and were advanced, for the times, from an engineering point of view. (Naish 1985, 37-38).

Lighthouses extend far back into the ancient world. The most notable lighthouse is that of Alexandria, one of the "wonders of the ancient world". In time other lighthouses in the Mediterranean world were built and lit. Gradually lighthouses also expanded into other parts of Europe. However the number of lighthouses were limited in number. There were perhaps fewer than three dozen by the beginning of the 17th century. (Stevenson 1959, 87). Many lighted aids in the medieval period were operated by monasteries, chapels and churches. (Naish 1985, 81-83). There was seemingly one lighthouse in the western hemisphere in the 17th century: Vera Cruz in Mexico. Two North American lights were established in the early 18th century: Boston in 1716, and Louisbourg, NS in 1733. (Whitney 1975, 17). Early lights were simple in the extreme. Lights were notably dim; however, during that time "light pollution" associated with the modern era would have been unknown. (Spotts CSM 2002, 11; Tyson NH 2002, 34).

It is a commonplace to lump all sea and harbor lights from earliest times under the heading of lighthouses. However, Naish in his extensive history of Seamarks seemingly does not regard the older lights as lighthouses. Instead he favors the term "fire towers". He notes that French authorities differentiated between "Phares" and "Fanals." (Naish 1985, 79-81, 18). Phares were not established until the 18th century for France. Fanals were minor lights. Naish notes the older lights "cast a glow into

the sky which would be visible by night and a big plume of smoke visible by day ... " He also refers to "Fire Beacons" in the Baltic in the 13th century which were open fires in a brazier. (Naish 1985, 18, 79-81). Other authors while retaining the term lighthouse yet give some attention to Fire-Towers. Sutton-Jones refers to one light as being of the "fire-tower pattern" in the 15th century and Edwards terms an early light at Dungeness as a fire tower. (S-J 1985, 13; Edwards 1884, 12). Fire Towers were simply towers with a open fire burning at the top of the tower. Though perhaps all lighted sea aids upon the coasts can be seen as lighthouses. That is, a structure displaying a light no matter how dim or primitive. Some "true" lighthouses display nothing more than a few dozen candles and that also was dim.

The first tower on a truly exposed location was that of Eddystone I which dates back to 17th/early 18th century. An older Lighthouse, Corduan in France, was the first wave-exposed tower. However, it was on a small island rather than on precarious sea rocks which might be above the surface of the surrounding seas in a precarious manner but largely submerged at higher tides. (Langmaid 1966, 14, 76ff).

One can speak of sophisticated optical apparatus and a variety of light energy sources for more modern Lighthouses. Lens, reflectors can be illuminated by various means including electricity, acetylene, etc. For early lighthouses there was no optical apparatus. The light source was the entire "package." Coal or wood in a brazier or grate was used overwhelmingly to 1800 and in some case into the 19th century. (Douglas & Gedye EB 1910, Vol XVI, 640). There were instances of oil lamps employed in the mid-18th century in England. (D & G EB 1910, Vol XVI, 640) and seemingly all 18th century lighthouses in the American colonies and nation employed lamps with wicks and oil. (Calahan 1960 EA, 506). Langmaid notes that before there were structures a simple fire often served as a beacon (Langmaid 1966, 35). But even when structures were employed, coal or wood fires continued in use though now positioned at the top of the structure. And frequently

these fires were in the open air even when on towers. (H & C 1975, Chs 3, 5).

## 1A2 Survey of Transportation-Markings Before 1750: Traffic Control Devices

Traffic control devices constitute an ancient practice. Very likely informal markings have been employed extremely early by humans wherever directional and distance information was needed. Lay refers to the use of "broken twigs, sticks or stones" as forming early markers. (Lay 1992, 189). Rocks, inscribed rocks, vertical rocks, cairns, trees, branches were also early forms. The Bible refers to signs and road markings which suggests a very early development. For example, the Book of Jeremiah refers to road marks and to signs. It is difficult to know with precision the types of devices since translations vary considerably. The *New American Bible* refers to road markers and to guideposts ("set up road markers, put up guideposts" from Jer 31:21). For the first term (road markers) seven of 14 surveyed translations (encompassing many of the major translations in the English language) offer road marks, road markers, or waymarks while four have some version of sign; two refer to cairns. Seven refer to guideposts for the second term, two to signs, two to landmarks and two have phrases instead of a specific term. An virtual introduction to transportation-markings terms is provided by the translations. (Translations listed in Bibliography).

An early form of organized, formal traffic control is that of the milestone. Milestones proved to be long lasting and easy to produce. They provided needed information in a time of few routes (and when only distance information was necessary. (Noble 1946, 4). A variety of sources note the use of such stones in the Roman era. They were of marble or granite, cylindrical or squared. Milestones or milliaries were roughly a mile apart and denoted distance between two points. Privately installed milestones continued in England until the mid-18th century. (Noble 1946, 4-8).

Signposts or fingerposts are another long-enduring traffic control device. Noble offers the view that fingerposts may predate milestones with the exception of Roman milliaris. (Noble 1946, 8). Eliot notes they are "defined in some dictionaries as a 'guide-board bearing a pointed finger ...'" (Eliot *TE*, 1960, 18).

Early signs, loosely defined, in the U.S. consisted of notches on trees. A single notch indicated a road leading to a church. Two notches denoted courthouse and three a road leading to a ferry. This practice began in early 18th century. (Sessions c1971, 2; Lay 1992, 191). Color coded painted bands on trees were employed in the early years of bicycles and cars. (Lay 1992, 191).

There is some evidence of pavement markings employed well before the modern era. A road project of the Roman emperor Trajan displayed elevated stones delineating lanes of road between Ezion-Geber to Petra. And stones were employed as centerline markings in a road between Mexico City and Cuernavaca as early as 1600. (Lay 1992, 191; Sessions c1971, 121).

## 1B Changes in the Context of T-M: The Industrial Revolution, 1750-2000

### 1B1 Introduction & Early History

#### a) Introduction & Terminology

There are a variety of ways for arranging the events of the Industrial Revolution. The basic categories employed here come from Louis Snyder. Snyder, a prolific historian of another era over many years, provides succinct and clear coverage of many topics. He also provides categories and descriptions conducive to this study. According to Snyder the Industrial Revolution can be divided into several subdivisions. The first segment, First Industrial Revolution, can be divided into a preliminary phase (1750-1830) and a main phase (1830-1871). There is a Second or New Industrial Revolution (1871 to the present). However, Snyder offered these categories in a work published in

1942. In an essay for *Collier's Encyclopedia* he spoke of a Third Industrial Revolution. (Snyder CE 1993, Vol 12, 765 ff). While Snyder did not date that Revolution it might have begun in approximately 1945-1950. Those three units will shape the survey that follows.

The term Industrial Revolution seems to have declined in usage in more modern works. Historical and economic works seemingly do not employ the term as much as in the past. One relatively new source that employs the term in an encompassing way is Peter N. Stearns in *The Industrial Revolution in World History*. (Westview Press 1993). He also mirrors Snyders three industrial revolutions: "First Phase, 1760-1880: The West Leads the Way," "The Second Phase, 1880-1950: The New International Cast," and "The Third Phase, 1950s-1990s: The Industrialization of the World". (Stearns 1993, ix-xi). Stearns, however, follows a more social science approach with less focus on technical developments. Other authors present variant periods of time. Alcock, for example, has a Second Industrial Revolution from about 1830 to perhaps 1910. (Alcock 1998, 201). O.I.E.W.H speaks of the Industrial Revolution as extending from 1750 to 1850, and a Second Industrial Revolution or Technological Revolution from 1945; the years between are unaccounted for. (O.I.E.W.H, 1988; 164, 339).

The revolutions, though not directly and immediately part of T-M, are germane to it. Events in the various revolutions will be given some attention in this study including growth of trade, changes in modes of transportation and in navigation, changes in preparing materials used in manufacture and in energy and propulsion. Science is also relevant to the study in matters such as optics.

Change in the 20th century represents a vast and bewildering enterprise that cannot easily be grasped. Nonetheless, significant changes in electronics, energy, communications and transportation that directly affect T-M are included.

#### b) Early History

Obviously, the Industrial Revolution did not begin overnight. It was not a case of production and trade existing on a tiny scale to be suddenly overturned by a vast increase in scale. Changes in techniques began well before 1750. However, many significant changes did take place in a relatively short time and many of these changes took place beginning about the middle of the 18th century. The Industrial Revolution was a rare event and extraordinary time "when the human species altered the framework of its existence ... ." (Alcock 1998, 168). It can be traced to a revolution in agriculture, notably increased population, inventions, a climate for entrepreneurs and greater capital. (Alcock 1998, 168).

A commercial revolution took place approximately between 1400 and 1700. (Snyder 1942, 331). This greatly changed a largely closed medieval economy. Markets were less often local and increasingly were on an international scale. But handicrafts were not up to the challenge of supplying goods for greatly increased trade. Knowledge both industrial and scientific was growing though at a restricted level. The growth in aids to navigation mirrored this earlier time of change though aids continued to be of a generally simple and primitive nature. (Wryde 1913, 323; Williams 1992, 93).

Early areas of change relating to transportation include the introduction of steering wheels in ships in the early 18th century as well as changes in types and uses of sails also occurred at about the same time. (Derry 1961, 188). Navigation techniques and equipment underwent significant changes as well including changes in maps, charts and nautical instruments. (Wryde 1913, 323).

Roads were limited in scope and often poor. Though this was less the case in France than in other nations including Britain (Derry 1961, 188). The first hints of railway transportation took place before the dawn of the 18th century though its practical impact was to be in the future. (Derry 1961, 331-332).

Changes occurring in the mid-18th to early 19th century relating to safety aids include propulsion (steam engine), metallurgy (iron and then steel), lighting (optics and fuels), and transportation (roads, canals, mechanical ships and rail).

## 1B2 The First Industrial Revolution, 1750-1870

### a) First Industrial Revolution: Preliminary Phase, 1750-1830

A key element of change during 1750-1870 is the increased production of iron as well as its quality. The production of iron had been limited and followed a primitive process. Smelting in older metalurgy required charcoal rather than coal (mining was difficult in part because of the problem of draining water from mines). Charcoal required enormous amounts of wood even whole forests. Coke began to be a replacement for charcoal in the early 18th century but that resulted in iron with high carbon content and lack of malleability. (Derry 1961, 146-147).

Smeaton, in 1760, developed a compressed air process for burning coke in blast furnaces. In the 1780s Henry Cort developed a puddling furnace that resulted in less carbon, but a product more malleable and with greater production. (F & D 1963, 364, 366). By the late 18th century the results of more and purer iron could be seen in notable examples: a cast-iron bridge in 1787 on the Severn by A. Darby that continues in use, and a barge of iron by J. Wilkson on the Severnship of iron in 1779 (Derry 1961, 450, 370).

Steel took on more significance as changes in coal and iron production energized new steel processes. Two notable changes were the Bessemer process, and the open-hearth furnace. Both changes took place in the mid-19th century. Those improvements were built on early improvements in the era of 1750-1820 though it was greatly affected by it. (F & D 1963, 463-464; Shubert (Singer) 1958, 54-55, 57-58).

Coal in itself produced great change. Heat so generated brought about steam propelled machinery. The old way of life was significantly changed as dependence on water, wind and animal declined and production forged ahead. Coal fueled machines began the Industrial Revolution. That revolution ranks in importance with the agricultural revolution. (Marks 2002, 95)

The steam engine was a seminal feature of the First Industrial Revolution. Probably few events of human ingenuity had the same measure of impact on civilization and the natural world. The steam engine has been described as the "quintessential invention". (Mokyr in Crouzet 2001, 101). Several earlier forms of steam engines were worked out in the 17th century. Thomas Newcomen in the 18th century advanced the engine especially with his work on the development of pistons though his work required further changes. James Watt examined and drew upon older efforts and then created the first effective engine during the years of 1763-1769. The steam engine drained mines creating a much larger mineral and metallurgy industry accompanied by locomotives for hauling coal from the mines. And it transformed the means of production from home industries to factories. (Snyder 1942, 338-339; Marks 2002, 109).

The steam engine revolutionised transportation beginning with ships driven by engines and followed by the use of steam engines in railways. The building of lighthouses was altered both by supply ships that were steam powered, and by the application of steam to the building of towers. Changes in lighthouse construction and equipment are chronicled in Bathurst's *The Lighthouse Stevensons* (Bathurst 1999). In time the steam engine was employed directly for safety aids; this is especially the case with fog signals. The steam engine transformed how things were made, how people lived. Transportation-Markings as part of the developing modern world was greatly altered as well. The need for aids to navigation was affected by the growth in trade which was engendered by the industrial revolution and this in turn safety aids allowed trade and movement of people to take place much more safely.

While railways in a more precise sense (That is, with flanged rails, steam locomotives, cars) began in the early 19th century there were primitive railways and pre-rail guided transport predating 19th century railways. (Derry 1961, 212-213). Early British railways dealt with mining operations rather than passengers. One such railway (early 17th century) used wooden rails and, presumably, was animal-powered. Iron-rails were first employed near the middle of the 18th century. The British parliament first approved a railway in 1801. That railway hauled building materials and was horse and donkey powered. (Blythe 1951, 13-14).

Britain long-remained premier in rail transport. However, earlier railway forms first appeared elsewhere. (Blythe 1951, 13-14). The Romans employed "rut-ways" to control wagon movements; early Greeks employed rut-roads which were perhaps similar. Primitive railways were found in continental Europe in the 16th century. (Blythe 1951, 13-14; Derry 1961, 167).

James Watt patented a variety of steam-powered devices designed for rotary movements though not for steam locomotives. (Blythe 1951, 14-15). William Murdoch, an associate of Watt, created steam engines though in miniature. Richard Trevethick created the first full-size steam carriage in the very early 19th century. His interest began in the previous century and included experiments with engines for road carriages, a boat as well as locomotives. Modern locomotives, in an early stage, are largely the work of George Stephenson in 1814. (Blythe 1951, 14-17; Ransom 1984, 11-12).

Railways of a more recognizable design are first found with the Stockton & Darlington Railway in 1821. This early line hauled freight only. The first passenger railway was the Liverpool & Manchester Railway in 1830. (Blythe 1951, 18; Derry 1961, 379).

Older roads were frequently limited and of poor quality. This was true in England where so much of the

Industrial Revolution began. However, French roads were relatively advanced by comparison. Thomas Telford created a road building process in England in the later 18th/early 19th century that bore some resemblance to Roman methods. The process involved heavy rocks fastened together with pitch, smaller stones and a binder of gravel. John McAdam created the "macadamized" process: small, hard broken stones that made up layers which were gradually consolidated by the weight of traffic." Asphalt or tar were added later. (Derry 1961, 431-434).

Canals had existed for many years on a limited scaled. But a new era of canals took place between 1770 and 1850. This era of canals was prompted by need for movement of both raw materials and manufactured goods (Boyes [McNeil] 1989, 477-478). A early steam locomotive was build in 1802 by Richard Trevithick. The original successful locomotive was created by George Stephenson in 1814. (Ritson [Singer] 1975, 84). Steam was applied to water transportation in the late 18th century. A steamboat built by John Fitch in 1786 travelled 20 miles while Robert Fulton's steam ship, the Clermont, travelled 150 miles in 1807 (Pearsall [McNeil] 1989, 527).

A communication revolution extended through the First Industrial Revolution. This included Claude Chappe's semaphore signal in the late 18th century known as visual or aerial telegraphy. This French system provided relative rapid passage of messages across France (Ohlman [McNeil] 1989, 711-712). Railway signals probably grew out of this early semaphore signal system though others would claim British naval signals were the source. Vanns refers to an Admiralty land telegraph as the source of railway semaphores. Shakleton notes that some sources refer to naval ship signals as the source of railway semaphore signals though he favors Chappe as the source. Possibly those suggesting naval ship signals as the source were confusing naval signals on land with naval signals at sea. (Vanns 1997, 10; Shakleton 1976, 229).

#### b) First Industrial Revolution: Main Phase, 1830-1870

The foundation phase of the Industrial Revolution focussed on inventions for textile machinery and the steam engine with many of those developments in England. The main phase(1830-1870) is a time of the railway, steamship, and telegraph. Significant progress also takes place in chemistry and physics with notable application of science to industry. Civil engineering is established as a profession leading to more precise and accurate machines and tools.

Cotton manufacturing, based on earlier inventions, became a vast industry. This industry, while not directly tied to Transportation-Markings, had a major impact by promoting growth of transportation systems globally. Coal and iron production increased greatly. Steel (which consists of various iron alloys) production through the Bessemer and open-hearth processes became a notable factor in the manufacturing of machines, factories, transportation equipment. (Bernal 1979, 520-524, 562).

Railroad construction is marked by rapid increase in the earlier 19th century. Snyder describes the 1840s in England as a "veritable railroad mania". (Ransom notes that before the "railway mania" there had been a "Turnpike mania" and before that a "canal mania." (Ransom 1984, 187). Thousands of miles were added and small systems become large ones through consolidation. There were also rapid increases on the European continent and in the US. Railroads moved raw materials and manufactured goods, and the railroads became the largest mover of passengers as well. (Snyder 1942, 343-344).

There were increases in ocean shipping in this time, but at a slower pace than that of the railroads. Propeller driven ships eclipsed paddle wheel by about 1870. Sailing ships for longer voyages were preferred even in the 1860s. The age of the steamship was after 1870. (Snyder 1942, 344). Changes in shipping mirrors the time of lighthouses and other aids to navigation: the apex of great coastal lighthouses was after 1870 as well; especially the last decade of the 19th and first of the 20th centuries. (Sutton - Jones 1985, Ch 3).

The later 20th century was a time of a near explosion of transportation and communication systems on a global scale. The era became a kind of super-information age bringing together the means of moving people, goods, knowledge, and tending toward if not a seamless web, at least a converging of seemingly diverse elements. Much of the foundation of that web took place in the 19th century. This was true not only of transportation but also communication systems though perhaps archaic from the perspective of the 21st century.

The telegraph was simultaneously developed in UK and US in the early 1830s. Inventions relating to electricity took place in the late 18th and early 19th centuries. An early version of the telegraph was invented and patented by C. Wheatstone and W.F. Cooke in 1837. At about the same time Samuel Morse invented a telegraph system in 1835 and patented it in 1837. His innovations including adding a telegraph key. (Ohlmann [McNeil] 1984, 714-715). Telegraph service was established by 1844 (Ohlmann [McNeil] 1884, 714-715). Snyder notes that the telegraph is to communication what the steam locomotive was to transportation. (Snyder 1942, 344-345).

Energy sources became expanded though much of the significant growth came in the Second Industrial Revolution. Electricity, though not unknown, reached a significant commercial scale of production only after 1910. Gas in the form of coal gas was discovered in the late 18th century. During the 19th century it developed into a commercial industry. (Derry 1961, 503, 511-513). Robert von Bunsen developed a burner that bears his name. It became the core idea for heating systems for both domestic and industrial use. (Snyder 1942, 346). Gas in various forms became a major element in improved lighthouse illumination.

In earlier times much of the production of goods was through the guild system and individual crafts people. In time, with the decline of guilds and need for more production, the putting-out system was adopted. This system put-out work beyond what the crafts people could

do. But it was limited in the amount of production it could handle. The factory system by contrast employed the new machines thereby vastly increasing production of standardized goods in contrast to home work and hand work. (Snyder 1942, 347).

While the first revolution was centered in England there were developments elsewhere. France was a significant factor in various kinds of goods but the actual process of industrial development was slow-paced during this period of time especially because of political institutions and turmoil. (Blanning 1995, 40-41). However, Fernandez-Armesto questions the mainstream view that France was industrializing at a slow pace and claims, in fact, that France was in an advanced state. (Fernandez-Armesto 1995, 389). A relatively small nation, Belgium, made significant industrial advances during this era. (Crouzet 2001, 116-117). Germany was to become a world industrial power but mostly in the Second or New Industrial Revolution. The U.S. -- which was to become known for massive production of standardized goods -- was mostly active in the Second Revolution as well. (Snyder 1942, 349-351; Stearns 1991, 35-37; Alcock 1998, 20; Crouzet 2001, 134).

### 1B3 New Industrial Revolution (1871-1940)

The New Industrial Revolution (or the Second Industrial Revolution) began in about 1870. By mid-19th century the United Kingdom was by far the most industrialized nation globally. Significant industrial change spread to the continent of Europe and the United States. A lesser measure of change was to found in Asia or at least East Asia and finally to Russia. (Snyder 1942, 355; Stearns 1991, 39ff).

Snyder writing in the early 1940s refers to the "Age of the Super-power." However, this did not refer to powerful industrial/military/political nations but instead to energy sources. The new power sources were oil and electricity. The energy sources that powered the earlier industrial development, coal and steam, were to be

eclipsed, supplanted by the "super-power" sources. Changes wrought by oil and electricity generated the new or second revolution (Snyder 1942, 355).

Both causes and effects of what can be termed the "New Industrialism" were brought about by several key factors: transportation and communication advances; mass production methods; capitalism (especially monopoly forms); large industrial/economic organizations. US and Germany were to become notable players in this new era. The US was important in mass production of standardized goods while Germany became a key force in chemistry-related areas and allied areas. (Snyder 1942, 355).

Petroleum was discovered in 1859 in Pennsylvania. Production was limited for several years but by 1880 some 10 million barrels were extracted annually. Advances in petroleum usage were brought about by demand (better lighting) and by technical advances (derrick, steam engines, drill bits). (Day [McNeil] 1989, 211). Early work in electricity extends back to the late 18th century. But only in the 20th century was a "deluge of inventions using electric power" unleashed. Electricity was found to have a very high transmission efficiency and was very flexible. The entire pace of life, economic and otherwise, was speeded up by widespread application of electricity. Electricity was employed for "machines, batteries, bells and alarms, cables and conductors, furnaces, heaters, generators ... ." Lamps included "incandescent, carbon, filament, tungsten, vacuum-tube" forms. (Snyder 1942, 355).

Railway mileage in UK for 1825 amounted to only 25 miles. By 1900 the figure had swollen to nearly 22,000 miles. Rail lines were found on every continent. The first US trans-continental line was opened in 1869, four years after the close of the Civil War. Between 1880 and 1890 some 70,000 miles of new track was built in the US alone. The late 19th century saw the use of larger locomotives, improved civil and construction engineering, larger bridges and extensive signals added to the railway infrastructure. "The railroad became literally the nerve system of the world's economy." (Snyder 1942, 357).

Internal canals of small size were long a feature of the landscape in a variety of nations. But canals of a different magnitude were added in the later 19th/early 20th centuries. In Egypt a canal was built at Suez between 1856 and 1869 with English control established by 1875. A French effort at the Panama canal was begun in 1881. However, bankruptcy by the builder led to purchase of the project by the US. US interests completed the waterway in 1914. (Snyder 1942, 358).

Long distance sea voyages continued to be the realm of sailing ships until late in the 19th century. Steamships were becoming more common yet they did not dominate marine transportation until the 20th century. (Snyder 1942, 358). Steam engines were a dominant energy source in other realms including industrial production and in railroads. They were also employed with some motor vehicles (Somerscales [McNeil] 1992, 273ff; McNeil 1989, 254, 258).

Research in the internal-combustion engine was well under way in the 19th century. Yet the steam engine was of far more practical significance in that time. In the 20th century no machine would transform life more than the internal combustion engine. The first wide spread usage of the engine was in Henry Ford's Model T. That auto nurtured mass production of vehicles and thereby altered not only transportation but passenger and freight movement hereafter. The US possessed 25,000 autos in 1905; by 1940 there were 34 million vehicles in the US (and 11 million for the remainder of the world. (Bernal 1979, 806-807; Snyder 1942, 358).

Motorized aviation began in 1903 in North Carolina. Advances in aviation were gradual; for example, small canvas covered planes were still made in the late 1930s though larger and more sophisticated models were beginning to appear. World War II would mark the beginning of a vast aviation world. (Snyder 1992, 358-359; Bagley [McNeil] 1992, 634-635).

Wireless or radio communication began in 1899. Practical radio was in existence by the 1920s. But again, much of the development would come in the war years and beyond. Safety aids employing radio began in the 1920s but a plethora of radio aids began only in the 1940s and afterwards. Research into radar, television and other electronic forms have pre-war antecedents though their significance comes much later. Telephones had not eclipsed the telegraph though its importance was growing. (Ohlman [McNeil] 1992, 726-727; T-M monographs).

#### 1B4 Third Industrial Revolution, 1940-2000

Louis Snyder viewed the the Third Industrial Revolution as starting in the mid-to-late 1940s. (Snyder CE 1993, Vol 12, 774). Peter Stearns begins that phase in 1950 (Stearns 1993, xi). 1940 is chosen here because so many developments took during the war years or at least had their beginnings. For example, radio navigation aids may have roots in an earlier time yet the modern shape of radio nav aids occurred substantially during the war. A metal such as aluminum, which was developed and produced well before the war, became a significant material only with war time production.

The older industrial revolutions consisted of fewer events though they were events of far-reaching impact. Great changes in transportation-markings are one dimension of that impact and an impact that is readily visible. But the Third Industrial Revolution has a possibly different character. Changes have been so diverse and numerous that it becomes difficult to chart out a logical and clear picture. The revolution is multifaceted and it is far beyond a merely technological event. Change has become transformational and enmeshes a very broad range of events. Transportation-Markings represents a few "knots" in the netting of enormous change.

James Nash (in a different context) notes that "the world is becoming increasingly a holistic system of inter dependent socio-economic systems, communications and transportation networks, and ecosystems." (Nash in Hessel

& Ruether 2000, 241). The place and role of T-M forms and how they are affected by technological change is deeply embedded in the current revolution.

The railway industry underwent vast change since the beginning of World War II. In the US steam locomotives entered into a steep decline especially after World War II. Already by 1960 most steam locomotives had been replaced. On the continent of Europe many changes were necessary due to war damage. However, electricity rather than oil became the significant energy source for railways in Europe. In more recent years special high speed trains have become a growing phenomenon both in Western Europe and in Japan. Change was slower in the United Kingdom because the older rail system largely survived the war and because of post-war economic austerity. However, steam locomotives remained a growth industry in some nations especially in China. Many steam locomotives were manufactured on a large scale even into the 1980s. (Ransom [McNeil] 1992, 593-606).

Jet aircraft were beginning to be produced before the end of the war but jet aircraft did not become common until the 1950s and after. Gas-turbine engines would play a critical role in jet craft. Helicopters also became a prominent feature of the later 20th century. Rocketry also contributed to a more exotic form of communication. The first satellite, Sputnik, was launched in 1957. Satellites have been launched for many purposes including nav aids. (Part III in McNeil 1992, 329, 536, 648ff).

The most notable energy source change is that of nuclear power. Nuclear energy has been a source of electricity though also a severe threat to civilization. Despite many drawbacks it remains a major source of electricity in selected nations. Traditional sources of energy such as oil and gas have been consumed at a rapid rate. Coal is possible under utilized but then it is a source of much pollution. Solar energy and wind energy are sources of increased electrical production though, to date, they constitute a minor element. Buchanan singles out the gas-turbine engine as a notable advance in applied energy use.

That engine is employed for jet aircraft and nearly all large planes employ some form of that engine. Some work on gas-turbine engines for other modes of transportation has been undertaken. Somerscales refers to the gas turbine engine as the "ideal prime mover" though the range of fuels that can be employed are more restricted than anticipated (Somerscales [McNeil] 1989, 340). Diesel engines have been greatly increased especially for trains and trucks. (Buchanan EB 1987, Vol 28, 477).

Many materials were invented and developed during the 1940 and afterwards. Aluminum, a relatively rare metal before 1940, became a key element for war production and has continued be so since. Plastics in some forms were in use before the war. But the broad range of plastics and related materials did not spring up until after the war. Other materials from magnesium to fibreglass have come into prominent usage. (Day [McNeil] 1989, 216, 220; Buchanan EB 1987, Vol 28, 477).

In many respects the contemporary world has become an age of information and communication. The centerpiece of that development is the computer. From small beginnings in the war years (though some theoretical foundations date back to the early 19th century). The computer has come to influence, even dominate many aspects of living. Microprocessors power, program devices of all sorts. The computer became relatively commonplace in commercial situations in the late 1950s. Personal computers began to be commonplace in the 1980s. A near epidemic of computers, networks has been witnessed since then. Safety aids are a specialized aspect of the information and communication revolution. They reflect the changes that have been brought about. (Ohlman [McNeil] 1989, 701-708; Buchanan EB 1987, Vol 28, 476).

## CHAPTER TWO

### VISUAL AIDS I, 1750-1920

#### 2A1 Introduction

Visual Aids I encompasses a lengthy period of time. It includes what can be termed the First Industrial Revolution (1750-1870 ) and also a portion of a Second Industrial Revolution. A more thorough study of the subject could easily divide the period into 1750-1870 and 1871-1920 eras. Since this is a cursory account 1750-1920 constitutes a single era though it has been bifurcated into two sub-periods,(1750-1870 and 1871-1920).

Events in Transportation-Markings mirror the events of technological developments. Early aids remain relatively primitive both in means of construction and in message-producing means. More modern means of building and more adequate lighthouse lens apparatus begin to appear only after 1820. By about 1870 more sophisticated and, what can be termed modern technology, become available. The zenith of lighthouses comes late in the 19th century and early 20th century. Early traffic signals and the beginnings of standardized traffic signs begin to appear in the last third of the 19th century as well. Railway semaphore signals of a more adequate design and improved color standards are also of that era.

The year 1920 may conceivably appear to be an arbitrary and even curious point for ending Visual Aids I. However, that date (and a few years before, after) can be an appropriate date for many forms of safety aids. Most types of all-lighted railway signals had been formulated by the very early 1920s; a new era of systems of control of railway signals begins at about that time. The pioneer era of traffic signals of the 1910s moves into the beginnings of the era of modern signals in the 1920s. Aero aids, which were few and informal shortly before, begins to take on a recognizable shape in a few years. The high point of visual aids for marine use is reached in that time and the beginning of a decline set in (though initially that may not

have been clearly seen). In short, the selection of the year 1920 can serve as a satisfactory point between visual safety aids in an early form and aids entering into mature forms, as well as aids entering their autumn.

## 2A2 Railway Signals

### a) Early Railway Signals

The term railway signals usually has the meaning of fixed signals whether board signals, cross bar and disc forms, semaphore signal, or modern color-light forms. However, before there were such signals there were direct human signals. The B & O employed hand signals in 1829 (AAR 1953, 6). Human activated signals were utilized in UK in 1830. Vanns notes that policemen displayed a red flag (and red lamp at night) for a period of several minutes after a train left the station. This might be followed by a caution (then a green flag, green lamp), (Vann s 1997, 9).

This practice of spacing trains is an early form of train control system known as the Time Interval system which proved to be a long enduring control system. (Vanns 1997, 19; Blythe 1951, 27). Armstrong refers to it as "time spacing" which suggests how it works (Armstrong 1957, 3). Jackson describes it as "a crude method of signalling ... ." (Jackson 1992, 296).

By about 1837 flags were mounted on poles which thereby became fixed signals, (Vanns 1997, 9). Flags were sometimes placed in stiff frame frames since flags might otherwise be limp in calm weather, (Blythe 1951, 30). A signal board might be termed a red flag even after discontinuance of actual flags, (Simmons 1986, 192).

Signal boards were in use by 1834. Boards were mounted on a spindle which could be turned (Hammond 1964, 66). Board messages denoted either "on" or "off". If the board faced the train crew that denoted danger (on). But if the board was on edge then the message's meaning was clear (proceed) and the board was off (and not visible to the crew) (Vanns 1997, 9). UK employs the terms on and

off to the present, (K & W 1963, 14).

Vanns speaks of positive (on), and negative (off) messages though active and passive would seem to be more appropriate. (Vanns 1997, 9). A positive message is one that is actually visible though the message would be red meaning danger. The negative (and passive) message was the absence of the signal board though that is clear or proceed in meaning. Negative and positive may suggest reverse meanings ( negative: no, positive: yes). A signal with a green face denoted caution.

One other early signal was the ball signal. It consisted of baskets, wooden masts, ropes and pulleys. The baskets became known as ball signals. If the basket was at the top of the mast it denoted clear (train gone). Such a basket was white. If half-mast then the train was to stop at the station. If at the bottom it denoted stop and stay. A black basket at the top of the mast indicated that a train ahead was delayed, disabled. (AAR 1953, 6; Blythe 1951, 30).

Signals in the form of single vane targets are still in use on US railways (and probably other nations) though not as mainline signals. They mirror the physical apparatus and meaning configuration of the early 19th century signals. See Camp's *Notes on Track* for extensive information on targets, (Camp 1903, 344-345).

Early signalling was decentralized and local. Such a situation precludes a precise chronicle of early signals though a broad outline of signal developments can be produced. Some evolution of signals took place in early 19th century though not necessarily in a strict progression of events. The earliest signalling involved humans directly employing flags and lanterns. Early fixed signals involved flags though attached to frames. Flags became replaced by boards. Messages and meanings followed one of two patterns. The first pattern was direct human use of flags (by color and also by position of the flag) which is reflected later on in semaphore signals. The other pattern was one of a visible and fixed object for danger; removal of which denoted clear. In some instances a third, and caution

message, was added. (Blythe 1951, 30-31).

#### b) Developments in Railway Signals

Further developments in signals may suggest semaphore signals since the semaphore became so commonplace. However, the cross-bar and disc occupies a niche in railway signals between the very early forms and the time of the semaphore's preeminence.

Early board signals (or pivoted boards) were less than adequate since there was nothing visible to indicate a track was clear. The Great Western Railway in 1841 solved this problem with its Disc and Crossbar Signal, (Simmons 1986, 12). In this signal the visible disc indicated clear and a rotating of the signal brought a cross bar into view which then denoted danger. A caution signal was also included in the shape of an arrow. When the green side of the arrow was visible a message of caution was indicated. But if edge-on it then it was not visible and the primary Disc and Crossbar messages were in effect, (Vanns 1997, 9). By the 1850s the board with its arrow-shaped (or "fantail board") became a signal in its own right as a station signal.

Lavelle describes a station signal of a different character which is, seemingly, not otherwise included in the literature. He notes that the Stockton & Darlington Railway workers placed a candle in the station window if a train should stop, but no candle indicated proceed. This is a version of visible= stop, and non-visible (in effect, non-existent)=proceed, (Lavelle 1953, 9).

The most important signal until well into the 20th century was that of the semaphore signal. It was originally developed in 1841 by C.H. Gregory for the London and Croydon Railway. This early version had three signal positions. The third (denoting clear) arm slipped into the post that upheld the signal mechanism. This is another version of the non-visible signal from earlier in the century. For a time lanterns were separate from signal arms though co-acting with them. Later on colored spectacles were incorporated into the arms and so positioned that a single

lantern would illuminate the correct lens as the arm moved the spectacle did as well. Continental European signals followed a variety of other patterns many of which are at variance with UK and U.S. practice. Often times separate arms and lamps is a common feature on the continent of Europe. (Shackleton 1976, 229; Blythe 1951; 33, S & B 1997, 447).

Semaphore signals were probably an outgrowth of Chappe's semaphore signalling system (for overland communication) in France, (Allen 1952, 140). The color patterns were determined at a conference at Birmingham in 1841. Colors and means selected were based on work of the Chappe Brothers in France. White, as the light that could be seen the longest distance, became the clear or proceed color. Red was the strongest of the remaining colors and it became the danger indication. Green then became the caution color. A usable yellow (that could be clearly distinguished from other colors) was not developed until the 20th century. (AAR 1953, 62).

Signals do not operate in isolation. They are grouped together into systems. Developments in the Industrial Revolution led to systems of train control. For example, the electric telegraph permitted the setting up of sections or blocks. These blocks were guarded by railway crews who permitted trains into blocks only when empty of other trains. Semaphore signals constituted the communication system that indicated to train crews whether entrance to a block was permitted. Interlocking systems created integrated groups of switch points, signals at stations and junctions so that all of the mechanisms and signals acted in a precise order. (Ellis 1966, 35; AAR 1953, 10, 13; B & M 1981, 55; K & W 1963, 6).

Fog signals are also found with railways. Many of these were detonators or torpedoes. They are associated with visual signals. This topic is taken up in Chapter 5.

#### 2A3 Road Markings, Signs, Signals

Road markings, signs, signals (traffic control)

devices) have an abundant literature in the 20th century (and perhaps late 19th century). But there is a paucity of information for earlier times. While it would be a caricature to suggest that some sources sum up traffic control devices history by speaking of Roman milestones then moving quickly to a single mid-19th century London traffic signal it would not be that much of a caricature. The organized Roman effort was followed by a decline in roads, and traffic control devices of whatever sort were localized and most often primitive. One UK source notes that the origins of fingerposts is "a little obscure" (Noble 1946, 9) and that can be applied to the entire topic. Early forms (pre-motor vehicle) do not manifest a very sharp demarcation between Industrial Revolution and pre-Industrial Revolution. The dividing line between eras is drawn by motor vehicles (and to some degree bicycles in larger numbers).

Eliot notes that uniform and standardized traffic signs are a result of the development of motorized transportation, (Eliot 1960, 18). Probably the numbers of signs and other devices is also a result. The less-industrialized era is necessarily more simple and accompanied by only limited documentation of what did exist. Eliot also remarks that "without the motor vehicle, highway signs might have remained primitive, local, and highly individualistic." (Eliot 1960, 18). This view needs to be qualified. Lay (Ch 2B2) notes that bicycles and cycling groups generated early groups of modern signs in more than a few instances.

Bicycles can be viewed as a result of the Industrial Revolution. An early form of bicycle was invented in 1839 and a more modern form was invented in 1885. (Lay 1990, Vol I, 29). Bicycles groups in Victorian UK became responsible for traffic devices (other than directional signs). For example, the Bicycle Union produced danger boards for crests of hills in the late 19th century. The Cyclists Touring Club also added caution boards. (UK MOT History 1979, 1).

The origins of carriageway markings are "somewhat obscure" though documentation exists for center lines in

Manchester in 1843. They consisted of white stones and lamps. (UK MOT History 1979, 5).

Traffic Signals are probably associated with motor vehicles yet an early version was installed in London in the mid-19th century (whose story is oft related) (O'Dea 1958, 80-81; Mueller 1969, 6-7). This version, produced by a railway signal works, consisted of lamps and semaphore arms. Messages consisted of red for danger and green for proceed though green remained a caution signal for railways for some years to come. Yet here green took on its later meaning of proceed even though the signal was the product of a railway signal concern. The signal was installed to aid pedestrians crossing a major thoroughfare at the Houses of Parliament. But an explosion in the gas line killed one policeman and injured two others. Lay refers to that signal as a pedestrian crossing signal (Lay 1990, Vol I, 32).

#### 2A4 Lighthouses & Other Fixed Lights

There were already signs of change in lighthouse structures and light apparatus before 1750 though the changes were limited in scope. The later 18th century and most of the 19th century were, by contrast, a time of great change for lighthouses. Many of the sea-swept towers were built during that time, the number of fixed lights vastly increased, and the dim lights of the early 18th century were replaced by lights of great intensity. The peak of visual (and acoustical aids) was reached after 1870 though many of the visual and acoustical aids were in place before 1870. This segment includes three topics: structures, lighting, and messages. Structures may often suggest spectacular rock lighthouses yet many more land lighthouses were built and a review of them is in order. Lighting includes several topics including the light that is produced, the illuminants, and the reflectors and lenses that project the light into the distance. Messages are concerned with the meanings ascribed to the emissions of the aids.

### a) Structures

Rock towers are very much a part of the first Industrial Revolution. Few, if any, true rock towers were built before the mid-18th century. This form of aid in the late 19th and early 20th centuries was clearly a continuation of the form established by such practitioners as Smeaton, Douglas and the Stevenson family.

Stone towers on precarious sites became a virtual art form. The stones had to be individually, precisely and closely cut by master stone masons. The stones had to have proper curvature for outside stones and the stones had to dovetail, vertically and horizontally, with adjoining stones. And the stones had to be assembled on land before shipment to the site.(Sutton-Jones 1885, 29; Naish 1985, 119). Edwards notes that a tower was a matter of three features: form, weight, rigidity. This meant there were three basic "ingredients" for a tower: the low center of gravity (large base which narrows with height); inertia (the sheer mass of weight generates stability); monolithic character ("like a solid piece of stone carved out of the quarry"). (Edwards 1884, 23-24). Witney, in referring to Smeaton's principles in the 18th century adds an additional principle: the foundation must be deep in the rock.(Witney 1975, 37).

Since many of the sites were masses of broken rocks the natural formations helped to break the force of waves so the tower did not receive the full force of the waves though the towers bore the considerable part of violent storms. Construction was difficult because frequently only a few hundred work hours could be found for construction even in the span of a full year. Both tides and storms greatly reduced the hours of work though a nearby ship or on-site barracks could keep the workers close at hand for even limited amounts of working time. Throughout the 19th century a considerable number of towers on all but impossible building sites were constructed in many parts of the world. One might note that few sites proved to be truly impossible. (Kettle/Findley 1896, 3; Sutton-Jones 1985, 29; Naish 1985, 119; and many other sources offer insights into

the sea towers).

A second form of lighthouse aid surrounded by water was the screw-pile lighthouse. The screw-pile concept was developed about 1830. It was used in 1836 to construct the Maplin Sands Lighthouse; one of four structures on shoals near the Thames entrance. The process consisted of driving iron piling into sea and harbor beds where a rock formation was not available. A considerable number of such lights were built in relatively shallow and often less-exposed locations in Europe, and the US. The upper structure could be of wood and iron construction. More than 40 such structures were built in the Chesapeake. Latter on caisson structures were often employed on many sites (see Ch 2B). (Naish 1985, 130; Kettle/Findley 1896, 4, de Gast 1973, 4).

Hague and Christie note that design and construction of land-based lighthouses was akin to that of other tall structures on shore.(H & C 1971, 100). Since the structure does not occupy much ground the issue of foundation problems was limited. The question arises of how older and newer lights differs varies greater. Industrial Revolution era lights involves mechanical means such as steam engines in contrast to earlier and primitive lights. Since open fires were employed to a late date a lantern house was often not present. The work of Argand and Fresnel meant more organized and more space-consuming equipment requiring larger lantern houses, more glass and iron work. An early US structure such as Sandy Hook displays smaller, narrower tower with small lantern house.(USCG 1957, 61). Some very short towers such as Point Bonita in California are nearly as much lantern house as they are "tower" (Le & We 2000, 56).

Hague and Christie offer a general account of construction and a typology of building materials which can form a classification of this material.(H & C 1971, 100ff). Hague and Christie speak of masonry towers which denoted stone rather than brick. Such towers leaked water and presumably rock lighthouses even more so. Such towers may have been coated with cement on the outside though plastered interiorly. Seemingly stone towers were

more common in England than brick. Brick, however, was commonplace in the US. Bricks could be made locally even when stone was less available. Many US west coast towers were made of brick. Such towers were coated with cement or plaster of some form on the outside and plastered on the inside. Stone towers are not entirely unknown on the west coast. For example, stone from Humboldt county was employed at St George's Reef, and stone shipped from England was used at Race Rocks in British Columbia. (Gibbs 1955, 11, 195).

Wood structures are less common and less enduring lighthouse forms. H & C notes that many such lights were built in pre-Industrial Revolution times. Leading lights often included a wood front light since it could require frequent moving. (H & C 1971, 103). A US light built just after the purvey of this chapter, Yaquina Bay (1871) is entirely of wood save foundations and it has endured to the present despite a long period of abandonment. (Le & We 2000, 169).

Iron lighthouses are very much a product of the industrial revolution. While some use of wrought iron dates back to ancient times extensive use of it as a large-scale building material could not take place before the 19th century. Such material could not be employed for rock lighthouses though it could find employment for land sites. In some instances the light was built at one place and then shipped long distances to its site. For example, Alexander Gordon cast a variety of lights in England then shipped them to the West Indies (Jamaica, Barbados, Bermuda). All were assembled by unskilled workers (Langston-Jones 1944, 193). Cape Mendocino in California, and Race Rock in Newfoundland are both of cast-iron construction. (Gibbs 1955, 56; Beaver 1973, 63).

Unlighted beacons are included in both pre-1750 and post-1870 segments. Since dates are only infrequently attached to accounts of beacons it is often uncertain when various forms of beacons began. Probably many traditional forms were in use after 1870 though technological developments may have influenced beacon design before 1870.

## b) Lighting

International Lighting Company (Interlight) periodically publishes a catalogue of their light bulb products. The front and back covers of the catalogues display a diverse selection of exotic bulbs for purposes ranging from projection lamps to medical lamps to stage lamps to navigation bulbs. For a few dollars (and sometimes more than a few dollars) a customer can quickly obtain technologically advanced bulbs for virtually any need. However, in the 18th and earlier centuries that was not the case. Illuminations consisted of candles or open fires or primitive lamps. There were few choices and they were all dim. Between the mid-18th and the late 19th centuries a revolution in lighting took place creating strong, clear lights that could be seen for many miles.

The initial advance in lighting was due to Aimee Argand. In about 1782 (writers give various dates from 1780-85) he developed the first effective oil burner. His design featured a tubular wick in which an air current was drawn up through the center. This resulted in greater aeration causing increased brightness and little smoke (O'Dea 1958, 200). Some sources credit him with adding a glass chimney thereby increasing aeration. However, more often Argand's brother is credited with inadvertently adding a glass container to a flame increasing its brightness; Argand quickly recognized the significance. However, Sutton-Jones instead credits Quinquet for the chimney and Carcel for "force feeding" the flow oil thereby improving the performance (Sutton-Jones 1985, 95).

Naish notes that Argand's lamp (referred to as a oil burner by some) transformed lighthouse engineering (Naish 1985, 116). O'Dea remarks that the Argand burner or lamp was invented at a time when a major increase in need for lighthouses matched greatly increased oceanic traffic as the Industrial Revolution became significant (O'Dea 1958, 200). While Argand's work was significant it was incomplete since the light went in all directions since it was not focussed in a single beam by the aid of a lens or reflector.

At about the same time as the development of the lamp work was undertaken on reflectors. Reflectors, in some form, may have been employed as early as the 16th century. However, significant work resulting in improvements and usage of improved reflectors had to wait until the mid-18th century. In 1763 rather crude reflectors were constructed of tiny shards of mirror glass embedded in plaster of paris. The lamps for that reflector were of a primitive nature yet the resulting assemblage increased the quality of light.(Williams 1992, 151). Parabolic reflectors in more refined forms included copper bowl (parabolic)-shaped reflectors coated with silver.

Sutton-Jones states that the "catoptric (reflecting system)" began at Cordouan in 1790.(Sutton-Jones 1985, 96). This seems contrary to the evidence though perhaps a more complete and finished system of mirrors and oil lamps was first used there. Naish notes that the Argand lamp in conjunction with parabolic reflectors was the optimal lighthouse system until Fresnel developed his lens. (Naish 1985, 117).

The most important advance in illumination comes from the French physicist and engineer Augustin Fresnel. Fresnel created a central bullseye lens with concentric glass rings grouped around the central lens. The individual rings were stairstepped so that the light source emanations were captured into a horizontal pencil beam. The light source was placed at the center of the lenses. This constitutes a refraction or dioptric process. Several of these lens panels were assembled on a carriage that could be revolved. (Sutton-Jones 1985, 96-97).

However, light escaped at the top and bottom of the assemblage. Fresnel later added reflecting prism rings that captured much of the lost light. This resulted in a catadioptric apparatus that both reflected and refracted light. Reflectors were not needed in the Fresnel system. (Sutton-Jones 1985, 97). There was also a long-enduring relationship between Fresnel and his staff, and the Stevenson family in Scotland. Seemingly there was cross-

fertilization of ideas between lighthouse optic designer and lighthouse engineer. In fact, members of the Stevenson engaged in optics designs and produced improvements on earlier work of Fresnel. (Bathurst 1999, 151-153, 218-219).

Illuminants for lighthouse lighting apparatus were not marked by homogeneity. A welter of fuels were experimented with and in some instances employed for long periods of time including fish, animal and vegetable sources. Colza oil was a long employed source. It replaced sperm oil in England after 1846 (and was employed in France before that). Colza or rape-seed oil is made from the seed of a species of wild cabbage. Olive oil found use in Liverpool in 1847. (Kettle/Findley 1896, 10). Lard oil replaced colza (rape seed oil) and sperm oil in the 1860s in the US. (USCG Strobridge 1974, 15; Conway 1915, 32).

Other oils included porpoise oil for a brief time in the U.S. during early 19th century (Strobridge 1974, 15). "Earth oil" was imported from Thailand in the early 19th century. That was seemingly an alternate name for petroleum.(Johnson 1890, 55). Rosin gas represented another short-lived experiment in the US (Rosin gas was made from rosin which is from the resin from distilled turpentine.(Strobridge 1974, 11; Putnam 1933, 189).

Mineral oils were to eventually dominate lighthouse illuminants. Though this was largely after 1870. The primary illuminant would become kerosene (termed paraffin in UK) Bathurst refers to post-1870 as the "Paraffin Age" which suggests how dominant that one fuel was to become.(Bathurst 1999, 252). This is in sharp contrast to the diverse fuels of this earlier time. Kerosene is a relatively old fuel though not heavily used at first. It was apparently first employed in 1846 in Canada. Witney notes that the inventor termed the product coal-gas though that often refers to a different prooduct.(Witney 1975, 26).

### c) Messages

It is not enough to have a strong clear light. It is also necessary to distinguish between lights. Today there are

several dozen variations of changing light characteristics from simple flashes to complex multi-characteristics (see Parts C/D, Datatabase II in this Series). At one time all lights were fixed in character. Stevenson in his survey (1819) found that over 85% of all lights were fixed (Stevenson 1959, 90). Chadwick describes one means of distinguishing different lights: build more towers each with a fixed light. For example, Casquet LH (Channel Islands) had three separate lights (Chadwick 1971, 59).

Possibly the first improvement in light phase characteristics came in Sweden in the late 18th century. A museum employee found a way to mechanically move the light every several minutes thereby creating an oscillating light (a light in which brief, spaced flashes alternates with long periods of darkness). Chadwick mentions a Finish light in 1814 employing this means (Chadwick 1971, 59). The same museum employee then devised a way to move the light apparatus by clockwork. It was found that a grandfather clock could be used to revolve the light. The first version used a chain with heavy weight to lower into the tower interior thereby causing a mechanism to slowly revolve the light (Chadwick 1971, 59). Witney offers a 1798 light on Cape Cod as the first light with a non-fixed character. A revolving screen periodically blocked light emissions (Witney 1975, 26). In both Sweden and the US, the late 18th century (and the early Industrial Revolution) saw the beginnings of mechanics applied to light characteristics.

## 2A5 Floating Aids

### a) Buoys & Technology

Buoys in 1870 were markedly different from those of 1750. The numbers of buoys had greatly increased, sound (bell) buoys were in operation, buoys were in deeper waters, light buoys were on the horizon. Wood buoys remained in service though in reduced numbers (at least proportionately) and iron buoys were becoming commonplace. While the years of 1750 and 1870 present a sharp contrast which is easily described, it is more difficult to describe the unfolding changes in the intervening years. Events are often not fully documented since maritime authors at times describe events in general terms (and often are influenced by other authors), or an event may be local and largely unknown outside of that locale.

The links between what took place in navigation and aids to navigation and events in the Industrial Revolution are reasonably clear-cut. The developments in mining coal, new ways of making iron and eventually steel are reflected in the use of boiler plates, riveting processes, shaping of the iron into chambers for buoys. (Naish 1985, 59). However, a cause and effect process between industrial change and aids is less easy to describe. Nonetheless, developments in science and technology are mirrored in buoys.

Naish notes that railways and iron ships were made possible by iron foundries and the technology for metal framing and fabrication. And this applies to buoys as well, (Naish 1985, 59). The construction is undergirded by a more basic change in creating the metal.

Change in buoys is intertwined with more than technological changes; economic expansion was also involved. Growth in trade required increased means of transportation which required safe route-ways. In addition, materials were needed to build transportation equipment and improve route-ways. Increased trade drove both new materials and construction. A key element in the process

required expansion of shipping which led to deep-draft ships going where ships had not gone before. And this required more buoys, including buoys of a more sea-going nature. It also required the marking of previously unused and uncharted waterways that were entirely unmarked. (Naish 1985, 59).

The role of iron in the development of new buoys is critical. Buoys required strength that could withstand the force of the sea. Bells and other sound mechanisms and eventually lighted buoys, required underpinings of iron and later steel. The new iron buoys were made of boiler iron plates riveted together, and they were made up of chambers forming water-tight compartments. (Johnson 1890, 45; Holland 1972, 207).

The first iron buoys were installed about 1850 in the US (Strobridge 1974, 12). 1860 may have marked the first iron buoy in England. Bell Buoys (see Ch 5) began in 1852 for the US. A number of other nations began using iron buoys at roughly the same time. Extracts 1861 provides details on early iron buoys in various European nations including the use of iron plates and rivets for constructing such buoys. (Extracts 1861).

Details on the types of iron buoys are sparse though Weiss refers to an iron can buoy in 1850. Possibly iron nun buoys were also in use. At some point spar buoys were made of iron as well as of wood though dates are uncertain (Weiss 1926, 39-40). Johnson in 1890 refers to three forms of iron buoys: nun, can and ice buoys though not spars (Johnson 1890, 45).

Early sound buoys include a bell buoy and a bell float. These are reviewed in Chapter 5, Sound Signals. Sound signals that are part of floating aids represent two forms of message systems. A treatment such as that of Part C and Part II encompass all floating aids together but this treatment separates sound buoys from purely visual buoys.

International buoyage (and beaconage) systems are a feature of the late 19th century and the 20th century.

However, local, national efforts in 18th century and the earlier part of the 19th century affected buoyage arrangements of a later time: local ideas in buoyage could spread to a much larger setting even global.

Naish notes two kinds of buoy differentiation that evolved over time: color and shape (along with topmarks). Color seemingly had limited value. Tonne buoys were covered with tar and thereby black. White did not stay white and a third color, red, had only a limited visual range. There were two shapes: barrel (tonne) and spindle or spar buoys; one buoy was flat on top and one was pointed. These shapes could be used to designate sides of channels. Topmarks could be added to the buoys. Those for can buoys were frequently in the shape of a can, square, or cylinder. Pointed buoys display topmarks in the shape of triangles or diamonds. Dating of topmark usage between pre-1750 and post-1750 is difficult to establish. Many older forms continued in use well into modern times and even to the present. (Naish 1985, 140).

#### b) Messages

Naish notes that while confusion over topmarks was substantial it was generally understood that buoys with flat tops became a port-hand aid while buoy with spindle or conical shape became a starboard-hand aid (Naish 1985, 140). Naish notes that a consensus had formed but remarks that Mersey Docks and Harbour disagreed. Somehow Mersey's approach is seen as running at variance with this consensus rather than seen as a valid approach on a par with the other view. Naish notes that Mersey "was one of the earliest authorities to develop a coherent buoying strategy." (Naish 1985, 140). Further, Mersey also employed red to starboard and seemingly before 1847 when green to starboard was established for ship lamps (O'Dea 1958, 86). Adamson refers to a report in 1842 showing red to starboard throughout the United Kingdom though that would appear to overstate the degree of usage of red to starboard (Adamson 1955, 353).

Both Scotland and the United States employed the

Liverpool system. (Naish 1985, 141). The Liverpool system continues down to the present: it is present, along with the contravening system, in every conference on buoyage. Today nearly all of the Western Hemisphere reflects Liverpool while most of the Eastern Hemisphere (save significant exceptions in East Asia) follow the reverse concept. Use of red buoys to mark the starboard side can be found in other nations as well. According to Extracts 1861 both Holland and Belgium employed black buoys to larboard (port-land) and white to starboard. Red was employed at junctions of channels. Northern Commissioners (Scotland) in that same document are listed as following the Liverpool system. (Extracts 1861, 20-21).

US. Congress in 1850 established a buoyage system in which red buoys with even numbers on right or starboard side entering from the sea while black buoys with odd numbers marked the left or port-hand side. Can and nun buoys are apparently not mentioned though those terms were in use well before 1850.(Johnson 1890, 45).

### c) Lightships

As noted in Ch 1, lightships date back to earlier part of the 18th century (Nore Lightship, 1731) (Naish 1985, 110). Despite primitive technology and living conditions, lightships expanded even before the 19th century. UK. added four more by 1800. Naish notes that in the mid-1980s that lightships were still in operations on the original five sites. There were lightship in early 19th century in other nations including the Netherlands, Germany, France, the United States. Technological advances affected lightships at an early date: the availability of chain cables became available in about 1820. Cables permitted lightships to operate in more open waters and with some degree of safety and reliability since ships could stay put. For example the North East Goodwin LS (in Dover Straights) was positioned in 53m of water and held in place by 466m of chain cable and a 5 ton sinker. (Naish 1985, 111).

Catoptric lamps continued in use on lightships

because of less weight. After 1850 "lanterns mounted on gimbals" were installed on lightships. This reduced the impact of the ship's swaying movements on the light apparatus allowing. UK lightships eventually substituted mainmasts for lattice-work towers. (Naish 1985 , 111).

The first US lightships was established in 1820 near Norfolk. This vessel was located in inside waters.(Conway 1915, 58-9; Weiss 1926, 35-36). The first lightship (or light-vessel) in outside waters was near Sandy Hook in 1823. Many of the early lightships were placed in more sheltered waters. The positions of lightships were dictated by the lack of iron and self-propelled lightships were not developed until the late 19th century.(Weiss 1926, 35-36).

## 2B Visual Aids, 1870-1920

### 2B1 Introduction & Aero Aids

1870-1920 is a diverse period for safety aids. It marks the high water mark for visual marine aids. It is a time of development for railway signals in which semaphore signals reach their zenith and many forms of all-lighted signals are introduced. Traffic signals and signs approach a recognizable modern visage. And embryonic aero aids begin to appear.

Aviation was becoming a practical reality in World War I. Localized, non-standardized aids for aviation existed just as comparable aids existed for road usage in the later 19th century. Though documentation for aero aids is not extensive. Breckenridge describes improvised landing lights during World War I as "burning gasoline or kerosene in old tin cans." (Breckenridge 1955, 6). Harvey refers to "Home-made boundary markers" painted in white. These were in use during the early World War I, (Harvey 1941, 84). Wind indicators of some sort or other were employed in World War I, (Harvey 1941, 84).

The 20th century was a century of systems and already in 1919 a first attempt at a system of aero aids was undertaken. The Convention on the Regulation of Aerial Navigation called for the "establishment of a uniform system of ground marks for the flying" though details were limited and any execution would have taken place in the 1920s. Even at that early date the need for such aids was recognized. (Convention 1919, 372; LN TS 1922, Vol 11-12, 261).

The few references to these early aids is not an indicator they did not exist. Ad hoc aids that existed were probably very localized and of recent installation. Probably early signs and marine aids also suffered from few written documents. If they fared better it may be due to length of time for those aids, and the larger area of operations.

Within a few years after 1920 aero aids were a

recognized and developing field. Very quickly aero aids became visible and organized. Perhaps ironically, radio aids became a reality more quickly than aero visual aids.

### 2B2 Traffic Control Devices, 1870-1920

#### a) Traffic Signs: Introduction

These fifty years mark an intermediate stage between localized, non-standardized traffic control devices and a far more organized and official form of devices. The Industrial Revolution(s) had great impact on the development of T-M in general. But rarely is that impact more clear than with traffic control devices (hereafter TCDs); a virtual cause and effect relationship is present. Eliot in 1960 noted that "[t]he modern age of standardization and uniformity in traffic signs ... is the natural and inevitable consequence of motor transport." (Eliot 1960, 18). And Krampen remarks that "the invention of the gasoline engine by Daimler and the rise of the motorcar establish the precondition of modern road traffic and thereby of modern road signs." (Krampen 1983, 39). While Eliot and Krampen are referring to signs these can refer to other tcd forms as well.

However, the motor vehicle is not the only form of vehicle generating standardized TCDs. The previously mentioned authors among others, also refer to the bicycle and the role of cycling clubs in bringing into being extensive sign systems. Though those signs were not fully standardized and at times localized yet many signs were generated. M.G. Lay goes so far as to trace the beginning of modern signs to cyclist clubs in the very late 19th century. Though that does not suggest that those signs constituted a fully modern sign system. (Lay 1992, 189).

Krampen notes that cyclist groups installed "the first true warning signs in the 1880s." (Krampen 1983, 37). Many of these signs were on hills and warned of the dangers of downward cycling. Examples of such signs include "To Cyclists: This Hill is Dangerous" and "Caution for Cyclists." (Lay 1992, 189).

Some writers speak of the essential role of motor vehicles in bringing about modern sign systems. Yet this overlooks the role of bicyclists in the process. Lay, by contrast, notes that cyclist groups developed into automobile organizations and the sign charters of cyclists moved to the auto groups. In short, non-motor vehicles played a major role in signage. (Lay 1992, 189).

In the US automobile clubs were also active in sign installation in the early 20th century. A second form of organization in sign work were the trail associations (sometimes referred to as route associations). The associations attended to making and installing signs on many routes. But this was not a standardized system and at times the sign work of the groups overlapped. Wisconsin in 1918 was apparently the first US state to develop a coherent and organized sign effort over a large area. (Sessions c1971, 79-81; Johnson 1964, 129-130).

#### b) Signs & Sponsoring Organizations

The Italian Touring Club was active in installing signs both in the late 19th and early 20th centuries. Krampen refers to more than a hundred and fifty signs installed in two years by this group. They were of cast iron and described as either signposts or simply signs. The League of Tourist Associations, an international group, convened a congress in London near the turn of the century which produced a proposal for organized traffic signs. PIARC worked on road sign proposals at the first meeting in 1908. And ratified later in that year. (Krampen 1983, 39; Lay 1992, 189-190).

Early prohibitive signs included signs whose purpose was to restrict, prohibit motor vehicles. A second form of prohibitive sign were speed restriction signs which began early in the 20th century in Switzerland. Krampen views the Swiss signs as predecessors of current prohibitive signs though speed signs can be construed as having more of a restrictive sign character than a prohibitive one. (Krampen 1983, 42-43).

National road sign systems in England, and Germany in the early 20th century established patterns for sign shapes that have taken on permanent meaning. For example, England in 1904 established a white ring for speed limits; an accompanying board gave numerical indications. Other examples included a red circular disc denoting no entry. An equilateral triangle in red, but without a center, designated dangerous curves, grades. Other information was transmitted through a rhombus-shaped board. Krampen notes the first three shapes are mirrored by current European practices (and other areas influenced by European forms). He views the rhombus as the possible antecedent of the heavily-employed diamond-shaped signs in the American system. (Krampen 1983, 44-45). [Rhombus: "an oblique-angle equilateral parallelogram" (RH 1980, 1133); Diamond: "an equilateral quadrilateral, esp. as placed with its diagonals vertical and horizontal; a lozenge or rhombus." (RH 1980, 367)]. The German Imperial Automobile Club created a series of warning boards in 1907. These represented curves, uneven roads and other hazards through appropriately shaped lines. (Krampen 1983, 45-46).

League of Tourist Association worked on the idea of international road signs in very late 19th century. But it was not until 1908 at the meeting of P.I.A.R.C. (Permanent International Association of Road Congresses) that international signs were first assembled. Ratification came about in 1909 at the First International Road Sign Convention. (Lay 1992, 189-190). It was a conference of governments though the driving force was the A.I.A.C.R. (Association International des Automobile-Clubs Reconnues). The P.I.A.R.C. had been discussed and, in fact, were already in use. The "Convention with Respect to the International Circulation of Motor Vehicles" was ratified in October of 1909. The first four international signs (usage was largely European in nature rather than reflecting many parts of the world). There were no specifications on color or form. The signs employed pictographs for railway crossing, open gutter across roads, cross roads, dangerous curves, (Krampen 1983, 52-53).

World War I altered road signs substantially. Signs, in some instances, were destroyed to thwart the enemy. The signs of UK were not affected in that way but, nonetheless, "many of the craft- designed signposts of the pioneering days of the motorcar disappeared..." in that time. That in itself signalled the demise of the home-grown signs era. France phased out the older cast iron plates of small size and installed large sign boards. The next stage in the international discussion of signs would take place in the mid-1920s. (Krampen 1983, 57-58).

An organized, applied approach to signs late in this period of time (1870-1920) is offered by Blanchard in 1919. His extensive tome divides signs into two classes: Distance & Direction Signs, and Warning Signs. Mile posts are described as "intermediate distance signs. There are alternate terms including Police and Warning Signs, and Sidewalk Signs. (Blanchard 1919, 1390-1393).

### c) Traffic Signals

Quite possibly the first traffic signal was that of London in 1868 which was discussed in Chapter 2A. A new, and apparently, improved version was installed in 1872 in London; this was also a semaphore model. There is a considerable gap in time between that signal and the next documented versions. Is there evidence for other signals in the later 19th century? Mueller, a historian of TCDs, finds the evidence to be lacking but offers the opinion that other signals probably did exist, (Mueller 1970, 7). A second writer, Lay, refers to a few semaphores in that time period (Lay 1992, 184).

The idea for traffic signals (US) may date back to 1904 and to one Ralph Lackner. However, no concrete action was undertaken at the time, (Sessions c1971, 21). Sessions refers to a semaphore (hand-operated) in Toledo OH in 1908. This version, like many early signals, displayed two colors (red and green) and words of "stop" and "go" were embossed on the lenses, (Sessions c1971, 22). A patent was filed in 1910 for a semaphore signal in the US but seemingly there was no actual signal nor

installation (Mueller 1970, 7). That patent, filed by E.E. Sirine consisted of "slowly-moving semaphores". MacKall notes that Los Angeles had semaphores very similar in design in operation in 1941 though the year of installation is not given. (MacKall 1941, 1). Mueller refers to a "Semaphore or Manually Operated Traffic Control Sign" in NYC about 1910. It is not clear if this is a signal. It included railway lamps for night-time use even if a sign and not a signal (Mueller 1970, 8).

The original mechanical semaphore in the US was apparently in Detroit about 1913. It included four blades that revolved with "stop" and "go" painted on alternating blades; lanterns accompanied the arms in red and green. The lamps were of railroad origins. In some instances beach umbrellas were employed as a sort of signal. Stop and go were painted on the umbrella with a police officer beneath the umbrella who rotated the umbrella according to traffic needs. (Mueller 1970, 8).

Semaphore signals in Richmond VA in 1916 employed white and red letters and lights instead of red and green. White is the old proceed color for railroad signals. Red paint and lights denoted the standard message of danger or, in this version, closed rather than stop. (Mueller 1970, 8).

Two early signal types in San Francisco have attracted attention in the literature; both date back to 1915. A model devised by B.M. Harris displayed double-ended arrows with the word stop displayed on the arrow; a motor revolved the device which also activated a whistle (see Ch 5). A second signal, by G.G. Caglieri, displayed red and green flashing, alternating lights. This signal lacked the semaphore character of many early signals. (Mueller 1970, 8).

There is a divergence of views on the original lighted traffic signal. A 1914 signal in Cleveland is often regarded as the first model. MacKall notes that "[t]his first installation had all the elements of a modern traffic signal system ... ." It could be controlled by hand or automatically.

Mueller also indicates historians regard the Cleveland signal as the first signal. He notes that James Huges filed a patent in 1913 and the installation followed in 1914 (though the patent was not granted until 1918). Evans supports this view noting Cleveland's signal was the "first recorded electric traffic signal control ... ." (Mueller 1970, 9; MacKall 1941, 1; Evans 1950, xii).

Sessions disagrees. He notes that it is "an article of faith" that the Cleveland signal was first. But he supplies evidence that suggests a home-made signal made of wood and with electric green and red lights was in operation in 1912 in Salt Lake City, Utah. Mueller supports the Cleveland contention and dates the Salt Lake City signal as 1916 or 1917. (Sessions c1971, 24, 27; Mueller 1970, 9). Lay's account relies on Session. (Lay 1992, 184).

The Cleveland signal appears to have been more conventional in construction. It had eight lenses (four red and four green). There was also a bell to indicate change of color (see also Ch 5). (Sessions c1971, 27). The first interconnected system of signals was in Salt Lake City. (Sessions c1971, 32; Evans 1950, xii). Seemingly the first three-color lighted signal was installed in Detroit in 1918. (Lay 1992, 187):

This coverage has been seemingly slanted toward the U.S. experience. However, much of the early signal development was in the U.S. Evans notes that traffic signals for general use did not begin until 1926 in Germany and 1928 in Great Britain (Evans 1950, xii).

TCDs at intersections were not confined to signals whether semaphore or lighted. A device known as the traffic tower was employed for some years both in Europe and in the United States. Traffic towers placed the officer above the level of traffic where visibility by officer and by traffic of officer was improved. Semaphore signals or lights operated by the officer indicated to the traffic appropriate action to be taken. (Sessions c1971, 33). Such towers were traffic control devices though through human activation rather than mechanical operation. The first such tower was

probably in Paris in 1912. It was not well received (or not seriously received) and was shut down after 22 days. (Mueller 1970, 7). The first U.S. tower was probably in Detroit in 1919 (1916 or 1917 are alternate dates) (Evans, 1950, xii; Sessions c1971, 35). This signal displayed semaphore arms with red and green lights. (Mueller 1970, 10). It has an alternate title of Traffic Control Tower (Lay 1992, 187). The traffic tower continued into this era though eventually it was superseded by traffic signals.

#### d) Pavement Markings

Pavement Markings has become a significant part of TCD in the 20th century. Though there are only limited references to such aids in the 19th century and early 20th century; to be sure, pavement markings were a minor aid during that time. There are selected forms of pavement marking that were in use from 1870-1920.

Two writers, Lay and Sessions, provide a brief overview of early uses of pavement markings with scattered references found elsewhere in the literature. Pavement lines may have been first employed in 1883 on the Brooklyn Bridge. Stop lines were used in Portsmouth VA in 1907, and that may represent the first such use. Center lines for bridges and curves were first applied in 1911 in Wayne County, Michigan; centerlines for streets began in Detroit in 1918. Crosswalk Lines were employed in NYC in 1911. Lay also includes the curious remark that a PIARC congress in 1913 expressed opposition to the painting of curbs and obstructions in white because this would be 'only of service to persons who are worse for liquor.' (Lay 1992, 191; Sessions c1971, 101-103).

#### 2B3 Railroad Signals

##### a) Types of Signals: Introduction & Semaphores

Railway signals, as is the case with all T-Ms forms, have an organic quality with several interwoven facets: first beginnings, a development stage, the mature aspect, finally, decline. The 1870-1920 era mirrors these dimensions.

Older forms are still present though no longer in a "growth phase" while other forms and topics are beginning to appear though not yet in the mainstream of railway signals. This review examines signals in use though fading away as well as newer forms well along in development and finally, forms beginning to appear on the horizon. The messages that signals emit as well as the physical signal is part of that review.

The semaphore signal represents an older form of technology that reached its zenith and almost simultaneously began a precipitous slide into near oblivion. Semaphores of various kinds (including UK but more especially systems on the European continents) remain dominant until well into the 20th century (even until after World War II). Semaphore signals shared a bifurcated existence with all-lighted signals in the US even relatively early in the 20th century. Semaphores reached technical excellence even as light signals of diverse forms were under formulation and, in some instances, finding practical usage.

In the United Kingdom the slotted-post semaphore displayed three-positions but with one position (the clear or proceed indication) "hidden" in the signal post and thereby producing a passive indication. This was a largely standard practice in UK. More critically, the normal indication (within the post was the clear indication rather than the danger position. This meant that snow and ice could freeze the clear indication inside the post thereby creating a false clear indication if the tracks were occupied. This occurred in 1876 creating an accident of major proportions. The slotted-post semaphore then went into a decline and eventually became extinct (K & W 1963, 9-10). An early replacement was the tumble arm or balance arm semaphore. This was designed so that a break in the signal would move the signal into the danger indication (K & W 1963, 9-10). In time this became a commonplace signal though complex and expensive to produce. Other semaphore signals were developed in time of a simpler design which displayed the danger signal as the normal signal and clear displayed only when required.

Older semaphores whether in UK, the European continent or North America employed mechanical control means such as wire or pipes connected to levers and in all cases operated by manual labor. Power-operated signals through interlocking altered semaphore operations greatly (AAR 1953, 66). New technologies including hydraulic pressure in the early 1870s, pneumatic power and compressed air signals were added in the 1880s. By the 1890s electric motors were used to control signals. In 1917 the Hall Signal Co brought out the "Style L", top of the mast semaphore signal. This may represent the high point of semaphore development. The semaphore signal had several drawbacks including two separate aspects: one for day operation and a separate one for night signalling (AAR 1953, 66).

Structures and lighting for traditional lighthouses is a major topic of discussion. This is less the case for semaphore signals. To some degree, structures are covered in a discussion of messages. AAR 1949 does provide an overview of structure. Arms or blades were of metal or wood. The ends were shaped differently depending on the message indication. US and UK style set the lens within the blade. In the US lens were often termed roundels and they were fitted into spectacles in the blade. Lamps were oil or electric. In European practice lamps and lenses were mounted on the post apart from the arm for day signals. (AAR 1949, 3-4; K & W 1963, 14; for signal codes for various nations--see Part F).

#### b) Types of Signals: Light Signals

Many older signals, whether semaphore or other forms, had lamps attached to them. The lamps could be seen but usually only at night since they were too weak for day operation. Large scale lighthouse optics probably could have been seen in the daytime but that was not an appropriate technology. In 1898 an all-lighted signal was installed for the Waterloo & City Railway in London (S & B 1997, 449). In 1904 the first daylight light signal in the US was installed in a tunnel for the Boston Elevated

Railroad. Semaphores influenced this signal, and to some degree, many other signals, since all-lighted signals mirrored the position of colors of the semaphore. (AAR 1953, 69-70).

Before long higher wattage bulbs, improved lenses, reflectors and other accoutrements could produce a quality daylight signal. Daylight signals were used in 1905 and 1906 but these were short range. Medium range (1500 feet) were employed in 1912 and 1913. The next year, 1914, a long range signal was developed. All of these signals were of the color-light signal variety. Other forms of signals soon followed (AAR 1953, 69-70). Daylight signals began in 1922 on the Liverpool Overhead Railway (S & B 1997, 449).

Pennsylvania Railroad introduced what can be viewed as a semaphore signal in all-lighted form with its position-light signal. In this signal a battery of lamps were mounted on a backdrop so that signal indications represented semaphore arms in lights but without arms. The lights were amber in color (The issue of yellow and amber is discussed in Part F in this Series). Other changes at the end of 1870-1920 time period are the searchlight signal in 1920 and the color-position light signal in 1921. The searchlight displayed a single lens with movable miniature lenses that moved into position or out of position as required and activated by a relay device. The color-position combined position light indications with the standard colors. While other configurations of color-light signals have been developed a full-range of basic types of all lighted signals were produced in these few years (AAR 1953, 70-71; Armstrong 1957, 12). This coverage may appear slanted toward the US. However, an English author, O.S. Nock notes the US was first in developing all-lighted signals. (Nock 1978, 780).

### c) Messages: Color

The physical signal mechanisms do not exhaust the subject. The messages that the signal emit are a subject in themselves though they remain closely intertwined with the

physical signal mechanism. Messages include colors, positions of arms and geometric-shaped boards, but that in itself does not give the meaning. Meanings can be ascribed to color, arm, or board that the signal displays. The topics of signal emissions and the ascribed meanings of signals are examined in this segment and related to the originating signal. Older signals and message were still in use in the 1870-1920 era. However those older elements gradually and probably unevenly, faded out of the railway enterprise while other forms by a similar process entered the picture.

Mashour offers an "incomplete precis", or thumb-nail sketch, of railway signals, from the 1840s until late in that century: "The first fixed signals appeared in the late thirties of the last century, consisting of posts with a pivoted flag or board in daytime and replaced by a lamp at night. Thereafter, disc-and-crossbar, or revolving boards of one shape or another, pivoted boards with a half-moon cut-out, disc signals, semaphores, etc. were introduced. Semaphores were soon fitted with lamps showing red, green and white lights at night, indicating 'stop', 'caution' and 'clear' respectively." (Mashour 1974, 22).

The use of the color white in the 1840s was a workable hue but less so in the 1870s. In the words of Vanns, there were many more "nocturnal lights" in the later 19th century. This added to the already established problem that if a red lens fell out of the lamp it thereby created a white light with the reverse meaning. For UK the use of 3-position semaphores was declining by the 1870s (since the slotted-post signal with three positions was declining in use). This meant that the caution color of green was less needed since two colors were sufficient. Green was then suggested for a proceed color and by 1876 limited use of green for that purpose was occurring. However, this created the anomalous situation of two proceed indications (white and green), and two danger indications (red and white) since white would then indicate an equipment problem and the need for the train to stop. (Vanns 1997, 33).

In 1893 the "Railway Clearing House" (UK)

recommended ending the use of white as a clear indication; green was then to become the all-clear color. It can be noted that UK did not face the US problem of having to find three clearly seen and understood colors.

Railway literature has only limited information as to when various systems dropped white as a clear color. Signal practices are not identical from system to system though the various systems probably exhibited some correlation of practices. For example, Great Indian Peninsula Railway (General Rules 1896) in 1896 employed red and green only; though that system was a British creation. Germany in mid-to-late 1870s employed a red, green, white pattern (Signal-Ordnung 1875); it is not known when a change away from white took place. The Transvaal railway in South Africa (which followed a Netherlands approach to signaling) employed red and green in late 19th though the exact year is not known (Starkey HDS 1944). It does predate UK influence in South Africa. Allen remarks that the US was as slow as European railways in replacing white with green. That may be true of continental European rail lines but UK had made the change years before it became common in the US (Allen 1982, 149).

The first use of yellow as a caution indication was apparently in 1899 on the New York, New Haven & Hartford Railroad (Am Eng & RR Jnl 1899, 124-125). Green thereby became the clear or proceed indication. However, for the most part the old color pattern continued. To employ yellow as caution was not a simple matter to accomplish. Color standards for various hues did not exist at that time. ARSPAP notes that "[r]eds varied from orange to a very dark red; greens ranged all the way from a yellow chrome to blue ... ." While yellow tints "ranged from a reddish-yellow, which was easily confused with red, to a greenish yellow which was easily mistaken for green." A consensus was forming that green was the correct color for proceed. But consistent and clear color standards had to first be established (AAR 1953, 73-75).

Professor E.W. Scripture stated in 1899 that precise

signal colors could be established. Corning Glass Works asked Scripture to undertake this work much of which was done at Yale University. Dr William Churchill, who was also involved in that project, set up an optical laboratory at Corning in 1904. More lab work and more papers (including two by Dr Nelson Black) between 1904 and 1908 created a large body of coherent information on the issue. The Railway Signal Association (RSA) was closely involved with these efforts. Finally in October of 1908 recommendations on colors and uses were made and passed by RSA. Color standards were included for red, yellow, green, blue, purple, lunar white. Specifications were also prepared that detailed photometric limits for the colors. Work continued for quite some years on the project though much of the work was completed in the pivotal year of 1908. The end result were multiple colors with clear boundaries and yellow as a safe and reliable cautionary color (AAR 1953, 74-75).

#### d) Messages: Arms, Boards & Tablets

A discussion of the development of color may cover the message dimension of all-lighted signals. But partly-lighted signals are multi-dimensional and emission of lighted colors is only part of the story. Semaphore signals, which reached their zenith in the early 20th century, include a multifaceted assemblage of arms, positions, shapes, and colors that encompasses a complex schema of messages. Semaphore signals can be upper quadrant or lower quadrant. The horizontal position denotes stop for both quadrants. 3-position UQ signals indicates caution by a 45 degree positioned arm above the horizontal position while a vertical indication denotes proceed for UQ. (Signals & Signal Symbols 1911 [RSD], 15).

Only a few LQ signals were of a 3-position nature which meant that two arms or blades were needed for most LQ signals displaying three aspects. Both caution and proceed are at a 45 degree angle below the horizontal in LQ. Contradictions in messages are avoided by different configurations employing two blades. UK and US forms are similar with lamps as part of the arm assemblage; many

continental European versions had lamps separate from arms. Variations are found not only with arms in themselves but ends of arms can also display different shapes (square, pointed, notched) each with different messages. Further differences in the appearance of arms is accomplished through the color patterns of signal arms depending on the system. The welter of semaphore messages -- especially when many different systems are compared -- can be bewildering. Part F in this Series offers further details on the subject; the individual signal codes are needed for a fuller explanation. (K & W 1963, 11-12; Allen 1982, 144, 149-151; Part F, 152, 157).

Signal boards, or board signals, offer a perhaps more arcane topic. Many earlier signals were at least partially of this form. Today, targets in US (and some other systems) suggest a direct link with the older boards. A key element in many of them is the lack of a positive proceed indication. Oft times the board denoted proceed when parallel to the track which means nothing of the signal was visible except the narrow edge of the board. Squares, discs, diamonds were typical shapes for signal boards. Southwestern European systems (France, Spain, Portugal) developed full systems employing boards. Other systems had partial systems based on geometric shapes (see Part F, individual signal codes).

A final form of less than fully-lighted signal message systems is that of movable signals. These include tickets, discs, staffs, batons, tokens which were moved by train crews between signal huts. This system required physical position of an object in order to enter a block (S & B 199, 453). In 1870 Tyler invented a token system that was "tied" to a machine at each end of a block. While there were many permutations the core idea was that a token could not be removed whenever a token from the opposite machine's token had been given out. The system led to much safer operations on single-line tracks (Field & Grant 1980). A modern version of key token involves keys with geometric shapes and colors assigned to the shapes. The historical underpinnings of these messages are obscure. (Field & Grant 1980).

#### e) Systems

Early work on blocks and interlockings began well before 1870 though considerable advances and applications took place after 1870. Allen notes that the early technological advances of block working and various technical advances were not massively and instantly adopted. He notes that the greater part of European railways "reacted very torpidly" to new ideas that aided safety. The new ideas cost money which did not immediately translate into immediate returns, and electrical devices were not perceived as reliable by railway people of an older school. Block systems were required by law in UK and France only in the 1880s. Early block systems in the US date back to the 1860s and became much more commonplace in the 1870s followed, in turn, by more sophisticated forms (Allen 1982, 148-149).

A vital element in modern railway signalling was the track circuit. William Robinson in 1872 (and Sykes in UK) created track circuits by employing an electric current through the rails. This provided a continuous current that tied together the entire system of signals. This system was automatic in that the trains running over the rails triggered the signals. In 1910 the Interstate Commerce Commission remarked, "[b]y this invention ... the foundation was obtained for the development of practically every one of the intricate systems of railway block signaling in use today, where in the train is ... *continuously active* in maintaining its own protection." (Simmons 1986, 197; Allen 1982, 148; AAR1953, 18).

Interlocking was at first manual in design and operation. It blossomed into more advanced forms involving pneumatic and electric forms in the 1890s. Mechanical forms did not come to the US until the 1870s though much earlier in UK. Newer forms included electro-mechanical, and power-interlocking (hydro-pneumatic, pneumatic, electro-pneumatic, electric among others). (AAR1953, 33-39; Allen 1982, 148).

## 2B4 Marine Aids to Navigation, 1870-1920

### a) Introduction

The 1870-1920 era is the high point of marine visual aids. While great improvements in lighting apparatus and in design and construction occurred before 1870, and major aids were built after 1920, the nearest to perfection and dominance of visual aids, especially great coastal lighthouses, occurred during this time.

The role of the Industrial Revolution is especially important in this time. Wiedemann in discussing the development of lighthouses notes the beginning of steam ships, the growth of routes (both coastal and oceanic) requiring new aids (Wiedemann 1982, 9). Ships required by the new trade were cargo ships as well as passenger ships. Increased trade included coal and iron and other products. Improved technology and increased travel and trade fed each other and generated new aids. Many of which were developed in the later 19th and early 20th centuries.

Lighthouse construction as a branch of civil engineering had set down many of its basic principles before this half-century span of time (Naish 1985, 129-130). While a great expansion of lighthouses was underway and some new projects presented difficult challenges to the engineers and builders, yet what might be termed the pioneer era was substantially over with: the hard-earned lessons of building on sea-sweep rocks and reefs established the how of difficult tower construction which was applied and refined during this era (Sutton-Jones 1985, 106-107; Naish 1985, 133).

Even before the perfected state had been reached the first tremors of a revolution that would eclipse and even overthrow many visual (and also acoustical) aids was afoot. Early work in electro-magnetic studies and early radio research were taking place at the same time as new fuels, new lamps, new lens technology were underway. Only in the 1920s would practical radio aids begin service yet a few possible hints that the visual (and acoustical), even if not

entirely obsolete, would be regarded as quaint and peripheral all too soon.

Much of what made these years so vital comes from seemingly mundane and, in some sense, easily overlooked elements. While many lighthouses had vast lens assemblies since the earlier 19th century they failed to project as powerful and as intense lighted signal as they were capable of. Illuminants and burners were lacking until well into the 19th century. A combination of new fuels and vastly improved burners would dramatically increase the brightness of the lights.

It is easy to focus attention on vast, soaring towers on seemingly impossible sites throwing out a beam seen twenty or more miles away. But lighthouses were only a fraction of marine aids. River and harbor lights, buoys, unlighted beacons were always numerically larger and many times over. These aids were often simple and even primitive. During 1870-1920 new fuels accompanied by technological changes created lights for buoys, and for shore and harbor lights that could work without human supervision for months or even years. The significant increase in metals and fabrication processes also altered the design and numerical quantities of aids, large and small.

### b) Illuminants, Burners & Accoutrements

The contemporary world, by and large, is a uni-energy world in the matter of lighting. Electricity dominates lighting. Lighting comes from a variety of energy sources (including batteries, wind mills, and solar power) but it is nearly all electrical in nature. Aids to navigation companies in the not so distant past offered gas-lights for many products. But there is little interest in acetylene lights especially in the US and more "advanced" nations (The Pharos Co.) continues to build acetylene apparatus but seemingly sales are outside the US). But a century or more ago electricity was rare and all sorts of liquid (and gaseous) products were employed for lighting. Following the spirit of an Industrial Revolution experimentation was rampant and a stable and

homogeneous phase was in the future. (See also Ch 2A4).

Many of the older illuminants (including the pre-1870 era) were from animal and vegetable products (Wryde 1913, 227-228). This may suggest a more ecological approach since they were renewable and did not deplete the petroleum reserves.

Colza oil, once a significant source, fell into disuse. In part, at least in the US, because production could not keep up with growing marine needs (Le & We 2000, 52). Lard oil was introduced into the US in the 1860s and became the primary illuminant until the late 1870s (Johnson 1890, 54). While it required pre-heating it provided a bright light and lard was cheap and abundant. But it too fell into disuse (Le & We 2000, 52). Oil-gas was introduced in the 1880s. It continued in use well into the 20th century. Oil-gas was frequently employed for lighted buoys. (Conway 1915, 34). Two forms are Blaugas and Pintschgas (WNID 1934, 1934).

One fuel source introduced in the later 19th century that proved to be more long lasting was kerosene. The term mineral oil that appears in the literature seemingly refers to kerosene. Some British sources refer to paraffin and that too refers to kerosene. It was far less expensive than animal, vegetable oils but, as Wryde notes, it needed different lamps than were available in 1868. (Wryde 1913, 227-228). Edwards offers the view that all mineral oils (for domestic use) are paraffin or altered type of petroleum. This included kerosine and other products including "crystal oil, petroline, astral oil ... ." (Edwards 1884, 35). As those lamps became available there was widespread use of kerosene. Already in 1885 kerosene was the mostly commonly employed illuminant in the US. According to Weiss it remained number one (at the time of his book). When combined with improved burners it provided a very intense and bright light (Weiss 1926, 35). Bathurst refers to the "Paraffin Age" that encompassed the years 1870-1950. (Bathurst 1999, 252).

One final source of energy continues down to the

present time though not often for major lights. Acetylene gas began employment around the turn of the 20th century (Strobridge 1974, 22-23). At first it was produced by on-site carbide generators but later it was provided in a compressed form dissolved in acetone. Gustaf Dalen in Sweden became a driving force in developing not only acetylene gas use but in providing the technology for unattended lights that were long-burning. (Sutton-Jones 1985, 132-139).

Illuminants were important but even more vital was the way in which the illuminant was ignited. Several different lamps were devised in later 19th and early 20th centuries that created a vaporized fuel which burned more intensely. Some of these vaporized fuel at the wick. However, A. Kitson in 1901 devised a system for vaporizing the fuel which became gaseous before ignition. (Bowen 1947, 20). This was coupled with the use of an incandescent mantle devised by Welsbach in 1885. The end result was a very brilliant light. (Wryde 1913, 229; H & C 1975, 156-157; Wiedemann 1982, 14).

While illuminants and burners are a pivotal area of innovation in marine aids to navigation there are other elements of change in this era. The previously mentioned Gustaf Dalen is a notable figure in a variety of aids improvements. He began by developing a safer system for storing, transporting acetylene gas. He also invented a flasher mechanism permitting long-term automatic operation of lights. His concern for economy led to the "sunvalve" which turned on and turned off lights even in dim daylight. Other products included a "mixer" which combined air and gas thereby producing a brighter flame. Much of Dalen's work took place in the first decade of the 20th century. The Pharos company (successor to AGA: American Gasaccumulator) continues to market acetylene lamps, flashers and sun valve very similar to those of the first years of the century. (Sutton-Jones 1985, 132-139; Pharos).

Many of the lens apparatus developments took place in the earlier and middle portions of the 19th century.

However, Sutton-Jones notes several inventions that greatly affected the workings of the lens between 1890 and 1912 (Sutton-Jones 1985, 106). A device was developed for supporting the optic (which could weigh six tons) on a sea of mercury. This meant less friction and fewer windings of the weight machine (which turned the optic when wound up). The optic could also revolve more quickly resulting in more flashes and a more intense light. The axis of the assemblage had traditionally been in the center however moving it to an off-center position allowed a greater range of light phase characteristics and characteristics more easily perceived by mariners (Sutton-Jones 1985, 106).

There were a limited number of electrified lighthouses in the 19th century. Professor Holmes "magneto-electric machine" was replicated and set up at a variety of English lighthouses. But the installations were expensive to build and they required a crew for shoveling coal and coal itself was an expense (Sutton-Jones 1985, 117). By 1880 oil vapor apparatus replaced the electric units. Sutton-Jones notes that "this paved the way for the giant lights at the turn of the century and the 'era of magnificence ...'" But this era of gleaming lenses, vaporized fuel accompanied by matching giant fog sirens was living in the shadow of great changes and this colorful era would soon be eclipsed (Edwards, 1884, 52ff; Sutton-Jones 1985, 117).

In the US there were some early attempts at electric light buoys in 1888. However, batteries were not available and electric cables had to be strung from shore. This proved to be an untenable situation since the cables often broke and the experiment ended in 1903. (Weiss 1926, 40).

### c) New Aids, 1870-1920

Several meanings can be gained from the expression "new aids." It can mean technologically altered but pre-existing aids (e.g., a long-enduring open-sea tower with a state-of-the-art vaporized oil burner). Or an aid so altered by technology that it is virtually a new aid (e.g., a lighted buoy). Or it may mean a new aid or one striking dissimilar

from existing forms of aids. The first form has been considered here but other forms of "new aids" have, so far, not been reviewed. To be sure, many aids in this period remained unchanged though increasing numerically.

Lighthouses had been built on sea-swept reefs, rocks but even in those conditions there was something solid upon which to build even if precarious in the extreme. Building a lighthouse where there was seemingly nothing of substance to build on is another matter. But in 1880 German engineers did build a light in shallow shoal water where nothing more than sand on the sea-bed was present. This was at Rothersand near the mouth of the Weser River. This was accomplished through using a giant tub or caisson. The structure, circular in size and of iron construction, was towed to the correct site then positioned and the water pumped out until the caisson touched bottom. An air shaft was built within the caisson to the sea bottom. Crews of laborers descended into the structure and removed sand until the caisson was firmly set on the bottom. Sand and concrete filled the structure. Upon the structure a light and living quarters were built (Chadwick 1971, 101-102; Johnson 1890, 37-40; Heap 1889, 126-127). The first US caisson light was Fourteen-Foot Bank Light in Delaware Bay in 1887 (Johnson 1890, 40). A number of Chesapeake Bay lights were also caisson in form. (de Gast 1973, 4-5).

A feature of many inland waters in the U.S. are post lights. After 1874 navigation became a major concern on the Mississippi and many other rivers. This required simple lights that could be easily moved. The lights (consisting of post, platform, and lantern) became a signature of many rivers. Early forms required daily care though eight-day lanterns were in time added. (Johnson 1890, 56). This topic is underrepresented in many sources. Dalen's work on acetylene and sun valve created lights not only for buoys but also fixed lights beginning early in the 20th century. But few sources detail what may be termed lesser lights. (Sutton-Jones 1985, 132ff).

Unlighted beacons included many forms that are long-enduring. The literature does not often provide

specifics regarding times periods and other factors. One Victorian writer, Edwards, details beacons for UK including the Thames yet dates for the beacons are rare. More complex forms were presumably of recent construction. Many sources offer much less information than that. (Edwards 1884, 118ff).

Two new unlighted buoys were added in 1900: Tall can and tall nun buoys. They were of iron construction and more visible and sturdy than older forms (CGAN 1977, 3; Strobridge 1974, 21). The availability of iron with industrial development also led to the building of lightships out of iron. The first such vessel in the U.S. was in 1882. (Conway 1915, 59).

#### d) Messages & Systems

Even in 1915 most lights were fixed in character. Conway's statistics in 1915 indicate more than two-thirds of all lights were fixed in character (that did not include lights such as those on the Mississippi which were all fixed). (Conway 1915, 36). However the improvements in major lights brought about more variety. Faster moving optics created more quickly achieved flashing characteristics as well as group flashing and occulting signals. The French lighthouse service introduced a quick-flashing characteristic in 1892. (Putnam 1913 *NGS*, 37). The group flashing characteristic was introduced by Chance in the late 19th century. (Langmaid 1971, 80). Edwards refers to a very slow flashing characteristic. (Edwards 1884, 80-81). Heap in 1880s provides a resume of characteristics: Fixed characteristics could be in white or red colors; the same pattern was available in flashing. Flashing could also be white and red. Several characteristics involved fixed color with flashes: white for both, fixed white with red, and fixed white with red and white flashes. (Heap 1889, 173).

Many or most lights were white in color. Some red lights were employed (Putnam 1913 *NGS*, 37). Yet seemingly green is rarely mentioned. Though it is found in railway signals. Colored lights, especially in an earlier era,

coupled with simple optics could not be seen at a considerable distance.

Systems are a feature of the 20th century. And this will prove to be the case in transportation-markings from traffic control devices to marine aids to aero aids and -- to a lesser extent -- with railway signals (that is, internationally agreed-upon systems; technical systems did exist). In a time of less technological development (e.g., early to mid 19th century) and with simpler transportation and safety aids, standardized groupings of aids and messages are less often the case. Nonetheless, some early systems did exist.

In 1889 the International Maritime Conference was held in Washington, D.C. While that conference did not face the problem of night lights it did establish red for starboard buoys and black for port as day colors. (Bury 1978, 136-137; Wiedemann 1982, 24; Parts C/D and Ii). This reflected an older English practice and it was in use for many nations. A survey in 1846 detailed English practice and the use of red especially at Liverpool which influenced many nations. (Naish 1985, 140). A British buoyage system in 1882 also included that use of red (as well as other provisions). (Nares & Bencke 1995, 165). However, ship lights were green to starboard and red to port. And harbor lights on the continent of Europe were red to port. (O'Dea 1958, 86).

In 1912 a second conference was held in St Petersburg which overturned red to starboard and decided on green to starboard both as day and night color (before that conference in Europe day color to starboard was red). This coincided with the practice of some European nations though not all. (Wiedemann 1982, 24; Parts C/D). G.R. Putnam offers a commentary on St Petersburg which is briefly summarized in Parts C/D. (US Lighthouse Service Statement 1927).

This laid the foundations for a split in color usage that has never been resolved. Even IALA in 1980 had to accept that the western hemisphere (plus parts of east Asia) use red paint, reflectors and lights to starboard) while most

of the eastern hemisphere employ the reverse pattern. (IALA 1975, IALA 1980). It can be difficult to fully grasp the underpinnings of a situation born in a limited historical and geographical setting that then spread to all corners of the globe and is probably permanently fixed in place.

## CHAPTER 3

### VISUAL AIDS II 1920-2000

#### 3A Aeronautical Navigation Aids

##### 3A1 Introduction to Visual Aids II

A key word and concept in the 20th century is the word system(s): systems in theory, in practice, in application. Systems can also take a centerplace in Transportation-Markings. The time of individual aids (whether coastal lighthouses, or local, home-made signs) has been largely left behind. There are some organized and inter-related groups of aids in the 19th century (especially in the last three decades) and early 20th century. But it is after 1920 that systems become a pivotal idea for a broad range of safety aids.

For Traffic Control Devices their history tends to be a story of systems: of conferences regional and global; an account more of groupings of signs and function than a recital of individual signs. Part E, *International Traffic Control Devices*, gives more attention to the plethora of conferences and agreements than to actual safety aids (a possible second edition would focus on types of aids more than on systems). Many marine aids were often singular though early conferences in 19th and early 20th centuries began a process of inter-related aids well before 1920. And an early system such as the League of Nations became overshadowed by the global system of IALA. Individual aids remain present yet at times they seem to have become submerged within systems of aids.

Arguably railway signals have always appeared within systems of some sort. Even early signals, though largely local, were often part of systems. This can be seen with the advent of the manual block system where a few signals were controlled by local operators. After 1920 various kinds of train control extended the railway signal system resulting in vast arrays of tracks and trains under centralized control of one sort or another. Early aero aids

may have been localized and homemade but very soon aids, whether long-distance airway or at a single airport, manifested an organized and systematic approach. Though aero aids did not become a significant factor in safety aids, until the 1920s.

While this coverage reviews the development of various safety aids it also surveys the diverse systems; individual aids are often seen in a context of -- or from a perspective of -- the system.

### 3A2 Early Development of Visual Aero Aids, 1920-1943

*Aeronautical Navigation Aids* (Part G in this Series) is the only mode-specific monographs that includes a somewhat substantial history of the aids. The other monographs only included a brief history or vignettes. The previous aero history is an element in this study. It is augmented by new material for the latter 20th century. Aero aids before 1920 were few in number, often homemade, with only a sketchy literature. Aero aids in the 1920s and 1930, quickly developed into an organized and recorded entity.

The controlling image of that era may center on airway beacons whether a great aerial lighthouse in Europe, or the vast system of beacons strung across American prairie and mountain. However, many of the lights were more prosaic boundary lights. The boundary light, as the name implies, outlined the total landing area of an airport rather than delineate approach channels, runways or taxiways. (Wood 1940, 311; Duke 1927, 122). The boundary light is the probable precursor of many contemporary forms of lights including threshold, runway and taxiway lights. One source speaks of "border lights" which well suggests its role. (Lighting ... LD, 7-31-26, 18).

Boundary light messages while not entirely standardized displayed some recurring practices. White lights were frequently displayed in the US though red was employed for many other nations. (Aids to ... AC 1929, 127). One source speaks of amber as a boundary color,

while another reference indicates international orange was employed. (St John 1934, 109; Finch 1938, 28). Fixed lights were commonly used though some flashing lights were occasionally displayed. (Black 1929, 160).

Early aviation it was soon recognized that some approaches to an airfield were to be preferred. These lights were termed range lights. They were positioned within the line of boundary lights and designated recommended approaches. They displayed green lights. (Black 1929, 16). One writer speaks of range lights as approach lights though they bore little resemblance to what became approach lighting. Range lights resemble threshold lights to a much greater degree. (Lighting of, AC 1928, 104-105). In time green also denoted the importance of a runway by the number of green lights. (Wood 1940, 311-312). Some boundary lights were equipped with red globes. Such lights denoted hazards near the landing area and were a supplement to obstruction lights. (Aids to, AC 1929, 127). The meaning of colors in the early era does not always correspond to current meanings. Though the use of green and red in US boundary lights reflects later usage.

Present-day airport lights rarely have a day dimension which is contrary to a somewhat early practice. Early boundary lights were mounted above cone-shaped objects of sheet metal. The color coding of the cones corresponded to the message pattern of the accompanying light. Regular lights could thereby be easily distinguished from other forms such as range lights. (Aids to, AC 1929, 127).

Obstruction lights normally display red lights. An older color term, ruby, presumably corresponds to red. (Lighting, AC 1928, 104) (Ruby is a deep red, carmine. RHDEI 1971 1250; ruby glass appears in marine literature as well). At least one source refers to an early obstruction in white. (O' Dea 1958, 105). "Red guard-lights" in a 1930s source is presumably is also an obstruction light. (Lighting the ..., LD 1926, 18).

Beacons are the most visible element in early

aviation aids developments. Light sources for these aids included incandescent, acetylene, electric arc, and neon energy forms. Most beacons either rotated or flashed; fixed forms were less employed. (Black 1929, 152; Lighting of ..., AC 1928, 105). Early U.S. airway beacons consisted of a uni-directional lamp that rotated and displayed a white light. Fixed course lights accompanied the beacon. Course lights displayed colored messages that denoted direction and identification of towers and fields. (Komons 1978, 135-136). A more modern beacon was introduced in 1931 with double-ends lights. (Komons 1978, 135-136; Airway Beacons, SA, 12-32, 323). A third beacon, the code beacon, was also introduced in the early 1930s. It employed Morse Code messages. (Breckenridge 1955, 9). The code beacon also served as an auxiliary beacon, and a hazard beacon. The hazard function is its current role. (Night Mail LD 1923, 16-17).

Komons notes that the essential notion of aerial lighting originated with marine aids. This fact influenced the placing of the Airways Division within the Lighthouse Bureau. (Komons 1978, 134-135). However, marine and aero needs are not identical and in the U.S. aero practice diverged from marine. By contrast, European aerial lighting tended to imitate marine lighting. Europeans created aerial lighthouses of massive power but intermediate landing fields with lights, as well as airway beacons, evenly spaced were absent. The European approach can be seen in the Dijon aerial lighthouse of 1923. (Aerial Lighthouse, SA 1923, 400). This single light marked the Paris-Algiers aero route. It contained two groups of lenses facing opposite directions. Each group generated a one-billion cp beam. Smaller mass-produced beacons also followed an aerial lighthouse mode. Aerodrome beacons in Europe and Australia were often of a red neon character. At the time some thought that neon in red was better at piercing fog than other colors. (P & B 1988, 153; Caldwell 1930, 316-317).

Wind indicators, both wind combs and wind tees, were an early feature of aviation. Their characteristic shapes have not changed greatly over many decades



(O' Dea 1958, 105). A full-range of signs and markings were not available in the early period. Though some markings, especially roof markings, proved to popular. Often they displayed the name of a town; at times the signs were floodlighted or the letters were outlined in lamps. (Air Markers LD 1923, 58; Young 1928 AC, 127-129). Other markers include circle markers and boundary markers. Circle markers marked the location of airports while smaller forms marked runways. (Greif 1979, 12-13). Boundary markers are the day part of boundary lights. Harvey notes the use of home-made markers in the early post-war era. These were often painted white and possibly lighted. (Harvey 1941, 84).

The simplicity of early aero lights gradually changed in the late 1930s when other forms of lighting were added. Early above ground cone-shaped forms were joined by semi-flush and pedestal forms; high intensity forms joined low-intensity lights. Strip lights joined boundary and runway forms. Strip lights delineated landing strips as opposed to a large landing area. They employed cone lights. Boundary lights continued in use while other forms were added. During the time of transition various lights overlapped and possibly contradicted one another. (Glidden 1946, 184-188; Wood 1940, 311, 312).

Early boundary lights took on an encompassing role: they outlined the entire landing area. However in time they evolved into a restricted role that delineated a precise runway. Range lights evolved into threshold lights. Red boundary lights became runway end lights. Early runway lights, known as contact lights, began in about 1940 displaying yellow (for outer runway), and white lights (inner runway). (Norvell 1940, 116). Boundary lights can be seen as antecedent to most newer forms though there is no simple linear evolution from boundary lights to other forms.

Taxiway lighting is relatively recent. Early airports were simple affairs with boundary lights and little more. If runway lighting was generally absent then taxiway lighting was fully absent. Taxiway lighting seemingly did not exist

before later 1938 but was in use by 1941 or 1942 (Douglas 1977). A 1946 US publication established the first taxi-way light standard (ANC 1946; also Navy 1946). Originally all taxiway lights were blue in color with most taxiway edge lights of semi-flush design; corresponding reflectors were available in the same standard (Navy 1946, 10-11).

The original US approach lights were neon lights in a short row installed to the left of the runway. Since the neon lights were brighter than other airport lights, it was proposed to use them day and night. Up to that time lights were only used at night. Tests indicated that two rows of lights were preferable to the now common single row. It is not clear when approach lights were first used. (CAA Pushes ... AW 1950, 47; Kroger 1948 AW, 21-22). One writer mentions this form of lighting in the 1940s while a second notes they began early in the 1935-1945 decade. (Wood 1940, 312; Breckenridge 1955, 15-16).

Most final approach glideslope indicators began after this period of time. However, the Royal Air Force began one early form (Tri-Color Glide Path Indicator) in World War II. That early indicator displayed an optical projector ground aid with three-colors. Messages included green denoting the pilot was on the glideslope; red indicated too low and amber too high. (Clark & Antonenko 1993, 51; Clark & Gordon 1981, 1).

Runway lights, as distinct from boundary lights, began between 1936 and 1939. (Breckenridge 1955, 13, 15-16; Wood 1940, 312). These lights known as contact lights of the marker type are the forerunner of runway edge lights. (DB Part II; Sharp 1944, 113). Such lights "enable[d] him [her] to properly contact the runway." (Glidden 1946, 186). Early lights were semi-flush. An early form displayed amber or yellow for beginning of the runway then white for the remainder. (Norvell 1940, 44). Threshold lights were green in color, and runway end lights displayed red as early as 1939. (Parnell 1988, 153). Beacon messages continued in established patterns. New uses (including beacons for smaller airports and cold-weather uses) were added but basic changes in beacons were lacking. (Breckenridge

1955, 14).

Many of the types of airport and beacon aids that are currently known existed in some form by 1944. While many changes were yet to come aero aids began to exhibit their modern shapes. The year of 1944 also marks the first major international movement toward shared standards and practices through provisional ICAO. (PICAO 1944).

### 3A3 International Cooperation in Aero Aids

Earlier coverage in this chapter refers to the early beginnings of international aviation cooperation beginning after World War I. This centered on the 1919 Convention described earlier. A series of Protocols to those early efforts were initiated between 1920 and 1929 though visual aids were not included. (Convention on the Regulation of Aerial Navigation 1919).

The United States, upon request from Canadian and British governments, called for an international aviation conference in September of 1944. The original organization was named PICAO, (Provisional ICAO). The conference, held in November and early December 1944 was the scene of several acrimonious discussions. The core problem may have been the increased clout of the US in world affairs, and the declining influence of UK. The issues included what directions to take in international aviation. Progress was virtually non-existent for weeks. Finally one document was agreed upon. Then others followed. Various technical annexes (including those dealing with safety aids) became part of the Convention at a later date. (H.L. Smith 1950, 163ff; PICAO).

The most significant safety aids document is that of the International Convention on International Civil Aviation. Provisions included navigation, technical issues and provisions for setting up ICAO. A permanent headquarters exists in Montreal. Publications and meetings have resulted in a large body of literature on visual aids over more than half a century. The Convention includes 15 annexes including those for visual aids and radio aids.

(PICAO 1944, Proceedings).

### 3A4 Development of Visual Aids, 1944-2000

#### a) Visual Aids Other Than Approach Aids

While many basic forms of visual aids were in existence by the time of PICAO/ICAO, many other, and more complex, forms came after that time. Major light forms during this time included the long-established boundary and range lights, obstruction light and aviation beacons, runway and taxiway lights, day aids. Approach lights require separate coverage because of the complexity and controversy.

Boundary lights by 1944 may suggest an obsolete aid yet they continued on in ICAO publications to and including 1976. Earlier light forms for ICAO displayed green lights for boundary and yellow for range (contrasting to older U.S. forms that were white and green respectively). By 1958 boundary lights became white and range became green. ICAO reserved these forms for water aerodromes and land aerodromes without runways. After water aerodromes were deleted the lights continued for airports lacking runways. US CAA included boundary lights in 1948 though by 1959 they were no longer included. (ICAO Aerodromes, Annex 14, various editions; CAA 1948).

Visual approach aids includes not only approach lights but also approach alignment systems (termed visual approach slope indicators). An early form, the Optical Projector Ground of the RAF in 1938, projected sectors of colored lights: green when on glide slope, red when low, amber when high. But it was not very powerful, and moisture could alter color appearance. Other versions have followed that early version. In 1954 an aid termed Mirror Deck Landing Aid was created for aircraft carriers. A central light was reflected through a mirror in alignment with bar of white lights when on alignment. Several versions grew out of the first model. (Clark and Gordon 1981, and Clark and Antonenko 1983; various editions of ICAO Annex 14, and Part G are the references for this

segment.)

Visual approach slope indicator systems (VASIS) or R-W VASIS (Red-White VASIS) began in 1950s; the shorter term can be employed though R-W VASIS is more precise. In an early form RAE employed several light boxes near a runway. When above glidepath, red lights were displayed; if low, then white lights. A mixture of red and white denoted on glideslope. It was approved by FAA in 1960 and by ICAO in 1961. Australians created T-VASIS which included white and red lights. If on alignment a vertical white bar appeared. Various permutations of a "T" appeared when high or low; a red T denoted "gross undershoot" position. (Clark & Gordon 1981, 1-5).

Because of shortcomings a new aid was developed in the 1970s termed PAPI (Precision Approach Position Indicator). This displayed white and red lights in boxes. Two white and two red indicated on glideslope while greater numbers of white or red indicate off glideslope in one direction or other. (Clark & Antonenko 1993, 58-59).

A variety of flashing or pulsed aids have also been introduced. Beginning in the 1980s, PLASI (Pulse Light Approach Slope Indicator) displays pulsed indicators whose meaning depends on rate of pulses. (Devore Aviation 1991; C & A 1993, 5).

Actual use of these aids is reflected in ICAO publications. Standard VASIS is included from 1958 to 1990 with an abbreviated form from late 1960s. T-VASIS first appeared in 1971. PAPI began in 1983. By the near end of the century only PAPI and T-VASIS remained. HAPI, a version for helicopters began in 1990. Various permutations of approach indicators are described in the literature. (Editions of ICAO AD).

50 years ago runway lights for ICAO consisted of edge lights and threshold lights. Threshold lights were green in color and that remains the case to this day. Edge lights were usually of two colors: yellow for the beginning of the runway followed by white. Center line lights were

added for major airports in 1964. Later on three patterns of color messages were displayed: white then red and white then red at the far reach of the runway. By 1969 runway end lights in red were added to the standards. Touchdown zone lights first appeared in Annex 14 for 1964. They were white in color. (Editions of ICAO AD).

Taxiway lights were traditionally only blue in color. That proved to be a distinctive hue which signalled the function of that segment of pavement. But more complex situations and the problem of a "sea of blue" (a large area of blue light) brought about changes. Older ICAO publications offered two options: blue on both sides, or blue on one side and yellow on the other. Later on, blue became the only taxiway edge color. Green was added when taxiways required center line lighting. And exit taxiway centerlines alternated green and yellow. (Editions of ICAO AD).

ICAO gives less attention to physical dimension of lights than US sources. This is the case in large part because ICAO's concern was with standards and recommendations for a vast network of broadly spaced airports. Originally, runway lights were semi-flush but they were gradually phased out in favor of elevated lights. By 1948 a diverse group of elevated lights had become available. Bartow and Line-Material promoted a narrow and "controllable beam" light fixture while others focussed on high powered, wide beam units; some of which had negative side effects. Semi-flush units were eventually re-introduced for inpavement usage. Other concerns centered on threshold and touchdown zone lighting. Both forms gained in use. (Editions of ICAO AD; Kroger AW 1948, 18, 21).

Aerodrome Beacons displaying white or white/green flashes (white or white/yellow for water) is a long-enduring aid. Only the ICAO 1951 edition lacks specific colors. The Identification Beacons is also a long-enduring aid displaying flashing messages in Morse Code. Obstruction lights historically displayed fixed red lights while Hazard beacons emitted flashing red lights. More recently the term

hazard beacon has dropped out, and obstruction became obstacle light. Some uses of flashing white lights has joined the traditional red messages. (Editions of ICAO AD).

Unlighted aids are a smaller topic though a persistent one. Aerodrome identification signs have existed for more than a half-century. Most other sign forms began in the 1970s. Various daymarkers have been in use with only the first edition in 1951 lacking them. Obstruction colors, flags, markers have been a constant feature. Approach day marking systems are a feature only in early editions. (Editions of ICAO AD).

Pavement markings have been the most complex, prolific of aids. Centerline markings are long-enduring; threshold, side stripe markings are nearly as common. References to daymarkings under that heading and water aerodrome markings are found only in early editions. Edge markings for taxiway are commonplace though earlier documents may refer simply to taxiway markings. The term daymarking is associated mostly with older publications. Holding position markings are more often of recent vintage. (Editions of ICAO AD).

## b) Approach Lighting

Approach lighting developments are pockmarked by remarkable confusion and controversy in the US beginning in the late 1940s and ending in the early 1960s. If technical considerations were uppermost in developing other forms of airport lighting then political considerations entered greatly into approach lighting. A re-reading of journal articles in *Aviation Week* over the course of the controversy may seem to suggest undiluted controversy. Yet there are also clear-cut developments as well. But the dominant role of the US, especially in the years after World War II, makes a recounting of the controversy necessary. Essentially, the approach light problem centered on whether a slopeline or a centerline system was preferable. While there were other possibilities those two forms were primary.

Despite the controversy, the outlines of the two systems that would eventually be employed were becoming clear already in 1948. And by the second edition of ICAO AD (1953) the primary forms of approach lighting were clearly in place. (ICAO 1948; ICAO AD 2nd ed, 1953, 58-60).

A pivotal figure in approach lighting is E.S. Calvert of RAE in the 1940s. His work in airport lighting long centered on approach lighting. His system consisted of a centerline row of lights but bisected by multiple crossbars. While the basic centerline has one cross bar Calvert's had as many as six. And instead of a multi-lamp barrette the Calvert system employed single (later double) lamps. And the cross bars formed a triangular shaped: wide at the outermost base then narrowing as the threshold of the runway was approached. The crossbars took on a central position in landing approaches; far more than in the centerline with a single crossbar. ( Four Honored 1951 AW 19; Charnley 1989 JN, 167; ICAO 1948, 19).

By 1952 the outlines of the two approaches was clear in ICAO. At that early date the system were listed under personal names: Calvert Centreline and Crossbar System, and ALPA ATA Approach Lighting System.. Both shed these names for more impersonal names: Calvert became known as DistanceCoded Centreline Approach Lighting System while ALPA became Barrette Centreline Approach Lighting System. (ICAO AD 1953; ICAO AD 1999).

In 1948 the US was close to approving the Slopeline Approach Light system. Slopeline displayed two rows of lights in the shape of a funnel with the narrow end near the runway threshold. When on course the pilot saw two linear strips of light; when off course the lights had the appearance of a slanting picket fence. Height and position of the plane could be determined by the direction and slant of the light units. (Wilson 1979, 238-239). Even though approval was seemingly near at hand, the CAA in 1948 was not only working on slopeline but also preparing tests for a pilot preferred centerline approach system. In 1949 ALPA (Airline Pilots' Association) strongly criticized the CAA

testing program at Arcata, CA. In part, because the slopeline lights in those tests were of greater intensity than those of the corresponding centerline lights. In 1950 slopeline was given high marks though the evaluating agency was the CAA who, obviously, had an interest in their creation. Despite that approval opposition to slopeline continued. Neither UK or France were enamored of slopeline and many US airports were unable to use slopeline. The CAA then reverted to a 1947 arrangement of a single row of lights in a horizontal plane but that did not gain support. (Wilson 1979, 240).

In 1950 IATA (International Air Transport Association), after a thorough study, approved the single-row centerline system which would eventually result in US approval of a centerline system. This form was favored by UK and various aviation groups. Condenser discharge lamps (high intensity flashing strobe lights) were added to a newer version of the system which were to remain a constant feature. (Wilson 1979, 241).

The older UK Calvert system underwent simplification by reducing the five transverse bars to three. Various manufacturers added to the complexity of early approach lights. Westinghouse contributed neon fixtures with separate flashing lights while Sylvania offered one fixture with both elements. AGA designed a funnel-shaped system with neon lights while CAA devised sealed-beam lights for its slopeline. Line Material/Bartow created a complete system with groups of dual sealed beam lights in two lines with four rows of fixtures for the outermost thousand feet, three rows for third segment followed by two rows and ending with a single row near the threshold. The left line of lights displayed green lights and the right side red lights. This suggests the pattern found in marine channels. (Kroger 1948 AW, 22-24)

It was thought possible that order out of chaos might be achieved during 1951. It had been noted that UK had long had a centerline system and that US pilots favored such a system. Tests of ideas took place over and over including at Patuxent Naval Air Station in 1951. Twice

international conferences took place in that year which were supportive of centerline systems. US Airforce, US Navy, CAA and the civil airline pilots were all entangled in the crisis. The Navy preferred slopline while the civil pilots wanted centerline. The Air Force opposed the centerline for the first 1000 feet though they would permit red runway edge lights within that zone. A possible compromise would have been to use centerline at civil airports and a modified version at Air Force facilities. The unresolved problem blocked international acceptance of the centerline (New Hope 1951, AW, 16).

And in 1952 the situation was unchanged. More evaluation resulted in strong pilot support from pilots and dissent from the military. CAA remained indecisive even though the pilot evaluations came from the CAA. And ICAO was to take up the centerline question in that year. Technical representatives agreed on centerline at ICAO in 1952 though no general vote had yet taken place. The impasse went even though the US military had apparently withdrawn opposition to centerline. However, a standard for centerline approach lighting was adopted by ICAO in that year, (Pilots 1952, AW, 75-76).

By 1955 no agreement had been reached in the US though yet more tests were undertaken. It was thought that these new tests, at McGhee-Tyson Air Base, TN would bring resolution. This specific system was a 3000 foot version. By 1955 there were two (US) National Standards, "A" and "B". "A" was a 3000 foot version while "B" was 2000 feet. The following year "A" became known as US National Standard Configuration A. (USAF, CAA Test, 1951, AW, 131).

Tests in 1957 focussed on strobe lighting experiments and seemingly those tests led to acceptance by the Air Force of centerline lights that would be near the end of the runway. This seemingly opened the way to approval of a centerline system. But even in 1959 questions about the quality of approach lighting were continuing to be raised, and its involvement in accidents was appearing in the literature. FAA documents suggest 1969 marked the

beginning of an officially documented approach lighting system though alterations were occasionally made. (USAF, CAA Tests AW 1955, 31; USAF Pilots AW 1957, 117.).

ICAO's approach lighting standards extend over a half-century. Changes have taken place yet an on-going centerline pattern has persisted. The second edition in 1953 provides two systems which can be recognized down to the present. More features have been added with the passage of time including additional lights and crossbars for higher levels of aviation. Category II and III forms include side rows of red lights and an added crossbar. Flashing lights are a standard feature for most approach systems. (Editions of ICAO Aerodromes, Annex 14).

### 3B Marine Aids to Navigation

#### 3B1 Buoyage & Beaconage Systems, 1924-1957

##### a) Introduction & IHB Efforts

The issues of international aids to navigation discussed in Chapter 2, Visual Aids I, continue to be issues deep into the 20th century and probably are permanent. The issues have a four-fold character: whether red is to starboard or to port; the reserving of the color green for wreck marking; the use of black as denoting starboard (or port), and the state of technology which long precluded the use of lighted buoys especially during an earlier time when systems of buoys were first developed. The use of green for wrecks instead of channels in itself is second only to whether red is to starboard or port as a factor in the unfolding conundrum (the US did not use green for wrecks but so used by many nations). (Parts C/D1988).

International Hydrographic Bureau (IHB) (Monaco), an agency heavily involved with surveying, long maintained a long-standing interest in safety at sea. Until the founding of International Association of Lighthouse Authorities (IALA) in 1957, IHB was the primary -- and virtually only permanent organization -- with that interest in aids to navigation cooperation. That interest began in the 1920s. IHB advocated an early conference on buoys, compiled a database of buoy systems, and published books of national buoy systems, (IHB 1926, IHB 1956, IHB 1971).

A 1919 hydrographic conference in London expressed the hope that nations would focus on buoy uniformity. IHB then undertook its own survey of all existing systems; IHB also planned to call its own conference on buoyage in 1926. IHB espoused a variety of proposals including basing any unification schemes on what the majority of states were actually doing. IHB insisted that channel lights were not to follow the color pattern of ship lights (when entering from seaward: red to port). Technical ideas including cardinal buoys, topmarks,

colors to be employed were also included. (IHB 1925, General Considerations).

##### b) League of Nations Conferences & Systems

The League of Nations (LN) took a direct interest in buoyage systems early in its life. One sub-committee meeting in London in 1924 considered the matter of buoys and set up a Special Technical Committee for Buoyage and Lighting of Coasts. Various meetings by the Sub-committee of Ports & Maritime Navigation and Special Technical Committee for Buoyage and Lighting of Coasts were held in 1925 and 1926. In 1929 a lengthy meeting was held at Genoa followed by a Conference on the Unification of Buoyage and Coast Lighting in Lisbon in 1930. (IHR 1995, 166).

The 1925 meeting (which represents the IHB-planned 1926 meeting) was a League of Nations-sponsored meeting (by the Technical Committee) though in agreement with IHB at Monaco. LN expressed interest in employing green for starboard day and night. IHB was opposed because green for wrecks was nearly universal. With the gift of hindsight, LN was correct in thinking of green as a basic color that could be used day and night instead of employing one color for day and a different color for night. But a half-century would lapse before that change was made. (IHB 1926 GC; IHR 1995, 166; IALA 1980).

The first entirely LN effort was in 1930 at Lisbon. The Committee for Buoyage proposed rules, and listened to comments from the members. Basic buoy shapes included conical for starboard and flat for port (which corresponds to those following Washington 1889 though with reverse color and meanings). A proposal was made for green as a channel side color but that came to nothing. Putnam of the US noted that 80% of the world's buoyage followed red to starboard and 2% red to port (LN 1930, 55 ff; LN 1931 Conference).

However, in 1936 the Agreement for a Uniform System of Maritime Buoyage (LN 1936 Geneva) promoted

green for starboard. Few nations followed that pattern (in Europe) but it carried the day. Of course a European conference at St Petersburg in 1912 had already laid the foundations for that decision. It was made because ship lights were red to port and green to starboard. Bury (heavily involved in the IALA system) remarked that red to starboard was "foiled by political intrigue and two world wars." (Bury 1978 *IHR*, 136). It is not clear what the nature of this intrigue was, but a small group did reverse a solid majority position. LN 1936 was not ratified. But following World War II many nations adopted LN 1936 to a greater or lesser extent. (*IHR* 1995; LN 1936; Bury, 1978 *IHR*, 136).

What is probably the last phase of League of Nations involvement in buoyage came about in 1957 during the United Nations era. The UN Economic Commission for Asia and the Far East set up a buoyage/beaconage system for the region's inland waterways. It was based on LN 1936. A notable feature is the title, "Uniform System of Buoys and Shore Marks for Inland Waterways in Asia and the Far East." This is probably the only such document to explicitly include fixed beacons. The Foreword notes "that the system is based on the logical idea that symbols used for comparable navigation marks should be the same whether they are floating or fixed." (UN ECAFE 1957, LN 1936).

### 3B2 IALA Buoyage System

The International Association of Lighthouse Authorities was founded in Paris in 1957. Aids to navigation problems would become a driving concern of IALA. By 1967 early work on a new buoyage system was underway. The task of the sub-committee was to prepare proposals for updating older systems and to note aids and markings that appeared since 1936. The hope was for standardization of aids to navigation. (Bury 1978 *IHR*, 135). One might regard a desire for international standardization to be a chimera shared also with TCD systems (see 3D).

The first stage of IALA's effort consisted in examining, improving harbor lights. But this proved to be too narrow in scope and a new study group was formed to supplement and update the Lisbon and Geneva efforts. The second stage was to introduce rules for "Ocean Data Acquisition Systems" and for recreation zone buoys. (Bury 1978 *IHR*, 135-136). But then a series of ship disasters occurred in the Strait of Dover and IALA was asked by Inter-Maritime Consultative Organization (IMCO) to take up the task of unifying buoy systems with marked attention given to wreck buoys. (Garrett 1980, 2-3). The study group for this task overlapped with the older group. Stumbling blocks for unification multiplied. The US adamantly refused to change from red to starboard pattern of 1889; both the US and Canada noted that North America was already unified and with a system simpler than that of LN. (Bury 1978 *IHR*, 136-137).

In one attempt to unify divergent ideas it was proposed ending cardinal systems in Europe. But that created opposition and the idea was dropped. (Bury 1978 *IHR*, 137). One early working plan called for various combinations of red to port which was unacceptable to US and Canada (Bury 1978 *IHR*, 137). And it was not realistic for Europe to change either (many other nations followed red to starboard or red to port as well). The impasse led to the idea of two regions each following one pattern of red to starboard/port. The first region, System A, was the first to be completed in 1975. System A combined lateral and cardinal systems with an expansion of the cardinal. Green became a channel side color which required a different handling of wreck marking. At about the same time the term unification was replaced by harmonization. (Garrett 1980, 1,5).

System B efforts began after System A was assembled. In many instances the red to starboard nations had nothing else in common except red to starboard. After four years of work System B had created rules similar to A save for lateral color usage. B was largely lateral but it did not preclude use of cardinal. If cardinal had been excluded then A and B might have greatly diverged rather than

follow parallel paths. (Garrett 1980, 6-7). In 1980 the IALA Secretariat noting similarities between A and B proposed one group of rules though with regional alterations. This was approved and one system resulted with regions A and B (Garrett 1980, 8-9). Western Hemisphere is in B (minus Greenland). Eastern Hemisphere is in A (minus east-central Asia: Philippines, Japan, South Korea). (IALA 1980).

The IALA system consists of several forms of marks which are often floating but can also be fixed. Lateral marks (with two regions) are the most basic element. Cardinal marks are black and yellow in color. The four quadrants are distinguished by arrangement of colors, topmarks and light phase characteristics. Other forms include isolated dangers, safe water marks (safe water all around the mark), special marks (yellow in color) which encompasses all varieties of special situations, and new danger marks. (IALA 1980).

### 3B3 Visual Aids to Navigation in the 20th Century: On the Cusp of Decline?

Automation is perhaps the pivotal word for marine aids to navigation in the 20th century. It was a key word for lighted buoys and smaller lights early in the century. And now has become operative for all forms. Traditional lighthouses, world-wide, are overwhelmingly automatic. In the past fifty years the process of automation has greatly accelerated. Even if many major lights outwardly appear much the same their very character is greatly altered. There are perhaps no overall statistics for the time of automation. The process on the US Pacific coast may be typical. The first automated light was at Long Beach, CA (known as the "robot light" established in 1949). The automatic process continued well into the 1970s. (Le & We 2000, 132).

On a basic level marine aids to navigation have remained much the same through the 20th century. There are, of course, changes in materials (acrylic and polycarbonate for lenses, fibreglass (glass-reinforced plastic), plastics, optical sensors, computer technology

among others) yet the kinds of aids and their messages and meanings have stayed much the same. Solar power and wind-power provide a different energy source for a growing number of aids but that does not alter the essential aids either. The Pharos catalogue outlines various new materials and processes. Sutton-Jones offers a chronicle or more contemporary aids to navigation practices and materials. (S-J 1985, Ch 7; Pharos).

The greatest change to visual aids are not new types of aids nor new materials or energy but a different form of aid: radio aids. The very existence of many aids has been threatened by that form of aid to navigation. Dark and stormy nights or thick fog banks no longer present the degree of risk they formerly had and thereby the role of the visual (and acoustic) has been permanent altered, reduced.

In 1987 Captain Nelson Keeler, USCG wrote an essay on the future of maritime navigation requirements. No specific mention is made of traditional lighthouses (but then the Coast Guard prefers to phase out or transfer out such aids). Keeler speaks of "less dependence on short-range aids" and "the need for the reinforcement received from visual aids" and "fewer" short-range aids. The emphasis is clearly on long-range aids which are all radio aids with particular focus on GPS. Visual aids while not entirely erased have declined in importance and numbers and have been reduced to role of "reinforcer" of radio aids. (Keeler 1987-88 *JN*, 290).

The visual, which in the early 20th century dominated marine aids to navigation (along with sound signals), is now reduced to a secondary state. New ideas have altered marine aids to navigation including different light sources, the energy sources, construction materials. Yet the form and message producing capabilities have, by and large, not greatly changed over much of the 20th century.

This may suggest that marine aids to navigation are becoming a sort of monoculture. What has become important and vital are electronic impulses even for local

navigation. What is acoustical has an extremely limited place; what is visual is increasingly in second place. There is less and less a principle of redundancy at work. The current situation already represents the present and increasingly will be the future. This is the state of aids at least in the perspective of those who place high value on effectiveness and efficiency. Keeler also refers to "risk analysis" in this process. Apparently whenever the risk analysis tips the balance then the visual aid has to go. (Keeler 1987-88, *JN*, 296).

A far different perspective on visual aids to navigation is offered by a study of Greek aids to navigation. Three researchers at the University of Piraeus statistically examined accidents in navigation in coastal waters and harbor approaches, (Englesou 1998 *JN*, 421-428). The study examined pre-World War II years as well as more recent years. Navigation today is studied with electronic devices (GPS; electronic charts, sophisticated radar, etc). The study found that the electronic aids did not lower the rate of accidents. They concluded that "the traditional light navigating aids are and will always provide an irreplaceable safety service for navigators." Such visual aids were technically simple, reliable, and external to the boat or ship. The authors also speak of the "friendliness" of traditional aids for mariners.

In cases where a marine problem developed it was an easy task to gain quick assistance by identifying a nearby light and then conveying that information to the nearest rescue center the location, name of the nearest visual aid (by identifying the light phase characteristic) which brought immediate assistance. Not only have new navigation systems not lowered navigation problems but the need for on-board systems to receive electronic messages also was viewed as a problem area: Shut-down of on-board systems leaves all electronic aids inoperative. Shore-based lights are not affected by anything onboard. (Englesou 1998 *JN*, 423).

Greek island navigation may be a special environment yet "the technological simplicity which offers

a high level of signal reliability and friendliness for the navigator" is found more with visual aids than other aids. That may suggest a lesson of large proportions: the old form of aid is not a mere reinforcer for electronic impulses but may have a definite edge over the electronic especially in local navigation, (Englesou 1998 *JN*, 421).

The Greek study examined the issue of aids from the view point of the receiver. That is a different perspective than beginning with the aids and ascertaining the cost effectiveness of various forms of aids. Perhaps determining what works for the user would alter an situation where the visual is reduced more and more while the electronic is ever more increased.

Bathurst in her study of the *Lighthouse Stevensons* echoes and expands the Greek study. She notes that no instrument is infallible and that can mean electronics both on-board and external. In the United Kingdom mechanical failure constitutes one-third of maritime problems and those failures can include run-down batteries and failed microchips. She ends her study with these comments: "The world has come full circle--from darkness to light and back again. But to most sailors the lights remain necessary pleasures. They have become devices of last resort, used, in the old-fashioned manner, when other methods have failed. They may have been superseded by technology but that technology does not take kindly to force-ten gales and flooding waves. If it collapses, as often it does, there must be other methods and older forms of guidance. Which is why the first thing that a sailor will see as he [/she] fumbles through the darkness toward Britain is still a beam sweeping over the water, shining out the same false dawn. The sea is a tamable thing, and the lights have made it safe." (Bathurst 1999, 261, 263).

## Chapter 3C Railway Signals

### 3C1 Railway Signals & Expansion: 1920 & Beyond

#### a) Introduction

AAR 1953 divides signalling in the US into before 1920 and after 1920 eras. (AAR 1953, 6). While that bifurcation is centered on kinds of control and operating systems it can also be applied to signals and signal messages. Those years beginning with 1920 witness many changes for railway signals and signalling. It was a time, especially after World War II, of widespread switching from semaphore signals to color-light signals. New forms and variations of color-light signals were developed especially in Europe. Cab signals and many electronic mechanisms also came into service.

Yet much of the ground work for these changes already had taken place: much of the glass technology, color standards, basic forms of all-lighted signals were in position for wide-spread usage by about 1920. One important area for signals after 1920: a variety of efforts would be made toward international cooperation; regional and trans-regional efforts generated new signal codes or at least general principles. Some forms of mode-specific safety aids had reached a mature level by 1920. For example, marine visual safety aids had reached their zenith by or before 1920. Railway signals were well along in development though changes were still in the future. But road and especially aero safety aids were in an early or very early stage. This has resulted in less extensive coverage both for marine and rail transportation-markings while aero and road is much more extensive. However, the coverage evens out when both visual aids chapters are considered.

#### b) Railway Signals

Many of the basic forms of all-lighted signals came into being in a matter of a few years; some of these forms are described in the previous chapter. Other signal forms were introduced in 1920 or just after. Searchlight signals

were introduced in 1920. (Tansley 1985, 425; AAR 1953, 70). Searchlight signals contain multiple colors but one lens system. Electromechanical systems moved the correct color assemblage into line as required; a newer version employs an optical system without mechanical movements. (AAR 1949, 11-12; Safetrans). In 1930 a new compound lens arrangement allowed the signal to emit long-distance signals with a very small bulb. (Armstrong 1957, 12). A committee of IRSE (UK) recommended three-aspect color-light signals in 1924 with a double-yellow fourth aspect when needed. UK aspects have remained unchanged since that time. (K & W 1963, 12).

In 1921 the color position system was made available. This signal combined features of the color-light signals with the position light signal. The position-light signal imitated semaphore arm positions but entirely through the use of lights all of which were of an amber hue. (AAR 1949, 19-20). Color position signals displayed colors messages as well as emulating semaphore arm positions. (AAR 1953, 70; Part F). Some shunting and other specialized signals have, to some degree, display message both by position and color yet they are not a full-aspect signal (Part F). The earlier stages of a new pattern of thought or of technological innovation can spawn numerous and variegated versions of a core notion. The numerous forms of all-lighted signals in the 1910s and early 1920 is a manifestation of that phenomenon.

Color signals as found in AAR publications follow predicable paths of triangular, vertical or horizontal designs. (AAR 1949, 5-7). After World War II color lights were quickly introduced into many European nations (since the war had destroyed many pre-existing signals). (Nock 1978, 780). Some of these followed conventional designs. In more than a few systems the lenses are almost scattered over the surface of the signal though patterns are present within the seemingly random appearance. Other patterns seem to reflect national characters: curved and almost sensuous design in France and angular patterns in Germany. (Part F discusses and illustrates the diversity of color light signals; further information is found in the

Database as well as sources for both monographs).

Cab signals have become a common signal form especially in high speed operations. (AAR 1953, 44-45). The ICC in 1922 introduced the idea of train-based signals along with various forms of train control (UK cab signals date back to 1906 but they were in an audible form--see Ch 5B). Earlier forms often emulated lineside signals though in miniature. In the later 20th century new forms of control systems generated new designs of signals. Alphanumeric and linear indicators (including speedometers) have replaced traditional cab signals with their miniature version of lineside signals. Lineside signals have declined as cab only signals have become more common though dual systems are still in place. Yet proceed, stop and speed information messages have been retained in many instances. (FRA-3, 1979, 123; Pore' ERS 1995, 299-301; Part F, 1992, 132, 146-148).

An early problem of signals was the quality of signal glass. This is discussed in Chapter 2. Much early work on this problem involved AAR and Corning Glass Works. (AAR 1953, 73-79). In the 1930s C.I.E. in Paris began extensive work on establishing standards for glass. In time the US AAR efforts moved toward conformity with C.I.E. standards. Though presumably much of the earlier work essentially conformed to those newer standards. Killigrew 1949 refers to a revision of AAR and NBS work in 1935 though without reference to CIE. (Tansley 1985, 425-426; Killigrew 1949 repr; CIE 1965).

Semaphore signals remained important during the earlier years of color light signal development. They suffered significant damage in World War II in Europe and other theaters of war. Semaphores were not so affected in the US though little manufacturing of semaphore signals took place after 1940 and increasingly new signals and replacement signals were of color light forms. (AAR 1953, 71).

### 3C2 Railway Signal Systems

Systems in railway signals can have at least two meanings: a large grouping of signals operating according to a pre-ordained plan. This may be the result of a conference of numerous railway signal agencies who fashion principles and guidelines to be followed by the members. Systems can also refer to a technical arrangement for operating a group of signals through some means of control. For example, a block system or centralized traffic control. Both forms are included in this study though the actual signals and their messages/meanings are the primary focus.

Signals and messages and meanings can be studied on their own with only limited reference to control systems. This has been true throughout the T-M monograph series including Part F which gave only limited attention to control systems. The Database (Part Iiii 2000) did include some coverage of control system terms. This monograph will follow the past patterns of T-M studies.

Systems of various sorts are a long-enduring feature of other T-M modes; even early groupings of buoys could be viewed as a system. There have been railway signal systems but they have largely been restricted to the railways of each nation: Each nation's signals, or even each railway, was independent of other national networks or individual railways. Signals in UK, US, Germany, France influenced other systems yet actual trans-nation systems of signals have only been of recent vintage. W.R. Smith notes this to be the case in Europe where German signals influenced much of central Europe. (Smith ORE-IUR 1987). In the past half-century several international signal systems have been undertaken including International Union of Railways (IUR), United Railway Organization (URO) and the Union of African Railways signal code (UAR).

International Union of Railways was formed in 1922. It has been concerned with standardizing equipment and operational methods among other matters. Most European railways are members as well as numerous railways in other parts of the world. IUR attempted to create a union-

wide system of signals in the 1950s-1960s. But the existing signal systems "were too well established" and the hoped-for system was not successful. (Smith 1986, ORE-UIC). It is not entirely clear why it failed. Perhaps the old systems of semaphores and boards in the early 20th century were already well entrenched by 1922. And the new national color-light systems after World War II were individualized efforts that became entrenched in turn by the time of IUR's effort. However, IUR has established general principles which can have an impact for changes in existing systems, or a foundation for new systems. (UIC Code 732, 1961). With the expansion of international high speed trains commonality in signals is especially important.

The Soviet Bloc created a signal system in the early 1960s.(URO 1962). The system was predicated on very logical, rational notions. It eliminated word titles and instead relied on numerical references only. The system is based large on green and yellow lights. Movement from green to yellow patterns denotes lower speeds. Many lights are in a flashing or a fast flashing mode which qualifies basic color message. The system presented a logical pattern of increasing and decreasing velocities. Red is included for stop messages. A variety of former satellite states employed some version of the system. (URO 1962; Part F, 231-232).

The Union of African Railways decided at its 1979 assembly to prepare a railway signal code. A working group was formed in 1980 and by 1983 a final draft of the code had been prepared. UAR anticipated a hoped for interconnecting of African railways, and the harmonizing of the existing signal systems was an early phase. The signal system was intended to not only improve safety, but also increase freight capacity and reduce labor costs. (UAR 1983, 1, 5-6).

The Code provides a window on African practice. There were two major strains of signals within the mechanical signal forms (French-derived board signals, and English style semaphores). Both French-derived and English-derived signals were to be included in the code for

whatever period of time they would exist. English signals were semaphores in form while French were in the form of signal boards: checkerboards for station protection signals and yellow diamonds for warning. The checkerboard version followed the old pattern of "invisible" indications for a clear indication (board parallel to tracks). The diamond was fixed and provide an unvarying message of warning (or caution). Color light signals were to be unified for all railway systems. (UAR 1983, 5-6, 7-8).

Control systems have direct bearing on signals. In an earlier era, block systems and semaphore signals provided integrated operations. Both signal workers and train movements affected the signal messages. This has becomes much more true with modern train control systems even to to the extent of sometimes eliminating lineside signals, and instituting nearly complete control of train operations. Now vast electronic system moves signals over a broad territory. Cab signals have been a major part of growing train control ideas. In the 1920s US ICC introduced an earlier form of ATC combined with cab signals,(AAR 1953, 44-45). Since then more encompassing forms have been introduced with a variety of forms of cab signals including alphanumeric and linear indicators. Some forms of control systems can be tied to conventional signals. A major form of train control is found with CTC employed since the later 1920s. (Armstrong 1978, 105).

### 3D Traffic Control Devices, 1926-2000

#### 3D1 Traffic Control Development, 1920-1950

##### a) Introduction, Europe & League of Nations, 1926-1939

The years following World War I to about 1950 are an extraordinarily diverse and complex time for safety aids as a variety of nations, organizations grappled with safety concerns for road and streets fuelled by rapidly expanding motor vehicle usage over much of the globe. A survey can do little more than hint at salient events of the time.

The nations of Europe held an early traffic conference in 1909 under French auspices (Convention 1909). A second European-sponsored conference took place in 1926 even though the League of Nations was in existence and beginning to examine traffic issues (The issue of authority in the 1926 meeting is not clear to this observer: there are indications that the 1926 conference shared characteristics with other pre-international organization conferences yet the League clearly had a major role). The 1926 effort was a modification of the 1909 conference though the earlier effort did not include shape or color for signs. International Conference Relating to Motor Traffic. (ICRMT 1926) examined the issue of shape to a degree though they did not include color. The now very common triangular-shaped sign can be traced to 1926. Four of the six signs (all danger) in 1926 are identical to 1909 versions. Traffic signals and pavement markings are not included. The term "signal" refers to signs. A substantial majority of participants were European though about 30% of the representatives were from the Americas, Asia, Africa. (ICRMT 1926, 7-9, 27-28-30; Krampen 1983, 65-69).

The 1931 conference was clearly under the authority and sponsorship of the League of Nations. However the title "European Conference on Road Traffic" was seemingly restrictive and only ten nations participated. Regulatory and informative signs were added to the danger signs of previous meetings. Colors for some classes of

signs were included though not for danger signs. Colors frequently involve options for use. Red is predominant for "Signs giving definite instructions." The Conferences work on shapes and messages would continue to have influence on future work. The red oblique bar makes its entrance at this conference. (LN ECRT 1931).

An examination of 1931 League of Nations and UN 1949 documents may suggest a great leap in TCD ideas from one document to the other. There is, however, a "missing link" and partly hidden link: A TCD system that never reached completion. The link is the "Draft Regulations" of LN's Communication and Transport Group during 1938-39. While not a definitive system it was approaching completion. However, the probable final meeting set for September 1939 was disrupted by the start of World War II. (LN Draft Regulations).

The arrangement of signs in 1931 is endorsed by the new study (1938-1939): triangular signs for danger, circular for both prohibitory and mandatory and rectangular for "caution or special indications". (LN DCT-CERCL 1939, RTS, 3). Danger signs were expanded with more variety in symbol forms. Considerable attention was given to issues of color with definite colors assigned to types of signs, specific symbols.

##### b) Americas, Africa, Middle East, Asia & Pacific, Old British System, 1922-1950

TCD development from the early 1920s to 1950 has a local and regional character. Cross-fertilization may have been at work but a substantially non-global approach was also at work. A survey of what was occurring in a variety of regions outside the continent of Europe therefore does not have a highly integrated appearance.

Traffic control device development in the Americas underwent several phases including the development of traffic signs in the U.S.; the various editions of the *Manual on Uniform Traffic Control Devices (MUTCD)*; the meetings and resolutions of the Pan-American Highway

Congresses and the American Travel Congress, and the *Inter-American Manual of Traffic Control Devices*. What took place in the US had an impact beyond its borders and takes on an international character.

Much of the work underlying the U.S. sign system can be traced to the early 1920s and the work of a few individuals. It is even possible to locate much of the cause for many traffic control devices to a few individuals and the maintenance/public work departments in a few US states. The first notable sign classification is that of the Mississippi Valley Association of State Highway Departments (MVASHD) (1923). (Sessions c.1971, 84). Officials of three midwestern states created the basis of that classification by proposing a system of sign shapes, colors and messages to MVASHD. (Sessions, 82). That system included round signs for railway crossings, octagonal signs for stop, diamond-shaped for "slow warnings," rectangular for "directional regulatory information," and route markers of a new design (Sessions, 84). The background of the signs was to be white with the letters and graphic symbols black. (Sessions, 84).

The MVASHD recommendations were passed onto the American Association of Highway Officials (AASHO). The State of Minnesota enacted the first *Manual of Markers and Signs* (1923) (Sessions, 84). AASHO presented the recommendations to the US Secretary of Agriculture (Oct. 1925) and it was approved the next month (Sessions c.1971, 92). AASHO then approved the report at their annual meeting. Before February, 1926, forty-one states had approved the report. AASHO published the *Manual and Specifications for the Manufacture, Display, and Erection of U.S. Standard Road Markers and Signs*. (Jan.1927).

The *Manual's* provisions included diamond-shaped signs "requir[ed] slow speed and caution"; square-shaped signs required caution because of adjacent conditions. (Sessions c.1971, 92). These signs had yellow background and black symbols. A manual for urban needs was promulgated in 1930 by American Engineering Council (*Manual on Street Traffic Signs, Signals, and Markings*).

(Sessions c.1971, 118). It was similar to that of the AASHO publication. The need for a single volume on signs, markings, and signals was soon realized and NCSHS and AASHO formed a Joint Committee in 1931 and the first edition of the *Manual on Uniform Traffic Control Devices* was published in 1935. The next edition, 1948, included greater usage of graphic symbols, and more pavement markings and advances in traffic signals (U.S. MUTCD 1948, 1-2).

A concern existed in the Western Hemisphere regarding uniformity in signs outside the US though that uniformity would not become a reality until 1967. (PAHC 1967 IAMM). Early efforts focussed on recommendations and a study of the issues. The problem was examined at the inaugural meeting of the Pan- American Road Congress in 1925. (Sessions c.1971, 129-130) which called for a study and adoption of a uniform system of signs and signals. The 2nd Pan-American Road Congress (1929) noted that the "European system" failed to meet American needs and that a study of signs was needed, and an international code of signs for the Pan-American Union nations was also needed. A "Convention on the Regulation of Automotive Traffic" was approved at the Pan-American Congress of 1930. (Sessions, 129-130). The 3rd American Travel Congress (at San Carlos de Bariloche, Argentina, 1949) proposed a unified American signs system with the US MUTCD as the foundation of it. (Sessions, 130).

The "Old British System" (OBS) of road signs stems primarily from the work of a committee of the British Ministry of Transport known as the "1933 Committee" (UK HADTS, 1-2). However, the foundations of British road signs can be traced to parliamentary legislation in 1903. The OBS continued its development until final alterations and extensions in 1957. The double-sign concept common to British signage (including British colonial and some commonwealths) also began in early 1903-1904. The approaches to signage between the older signs of continental Europe and Britain bear some resemblance. Variations were noticeable though some cross-fertilization may have taken place. A publication on signs in 1921

strengthens the two-part sign concept by adding a symbol and word inscription to the rectangular plate below the triangle.(UK MOT, 1-2).

In 1931 the Ministry of Transport established a committee to study the sign system. As a result of that study, new sign formats were added.(UK MOT, 1-2). That study provided foundations of the British sign system until the establishment of the UN Protocol system (1964 and 1967). A later committee in 1944 proposed additional changes; however, those changes were not issued until 1950. Limited alterations in 1957 added pictorial signs. The 1933 document predominated OBS's life. OBS reached its final state by 1950. (UK MOT, 1-2).

OBS signs are divided into two categories: Prohibitory & Mandatory, and Warning & Informative. All signs are two-part signs. The upper part is circular-shaped and the lower part is rectangular-shaped. Many of the upper signs had either a red ground, or red border. The lower signs had black rims, ground and legends. Warning and Informative signs displayed a triangle and a white ground and red border. The lower part was usually rectangular with black rim, symbol and ground. (UK MOT).

The development of carriageway markings was independent though parallel to that of signs. (UK MOT, Addendum, 4-5). Carriageway markings may have begun in early Victorian Britain but did not become relatively common until after World War I. In 1926 a circular published guidelines on the use of white lines which the "1933 Committee" incorporated into its work. White lines were used for several purposes though not for centerlines despite the committee's aware of the US usage. Pavement markings were expanded by the 1944 Committee. This expansion included lane markings. Reflective "buttons" ("Cats-eyes") were first installed in 1935 and became common.(UK MOT, Addendum, 4-5).

Development of traffic control devices in the vast area stretching from the Cape of Good Hope to the Suez Canal and onto the Pacific, was more limited than that in

Europe and North America. And much of existing development was largely dictated by groups and nations outside of those regions continents and islands.

Probably much of Africa followed the "European system" after the 1926 agreement. (UN 1952 GERSS, 12). But the 1931 Convention held sway only in North Africa with variants in sub-Saharan Africa. There were efforts at unification in Africa, and a system of signs was proposed for Southern Africa before World War II but the war precluded much use of the new traffic signs. In 1950 a Johannesburg traffic conference was to greatly alter sign patterns in sub-Saharan Africa. (UN 1952 GERSS, 12).

Asia and the Pacific safety aids present a mixed pattern before 1952. Some nations (Iran and Thailand) followed the 1931 LN system while other nations employed the "red hollow triangle surmounting a rectangular plate" with symbols from Old British System. (UN 1952 GERSS, 13-14; OBS). Those latter nations included the nations of the Indian sub-continent as well as Malaya, Australia, New Zealand. All of which were affiliated with UK in some sense or other. UK was the source of the OBS.

The Middle East nations also followed the European system though road signs were frequently limited. Egypt and some other nations added supplemental plates to primary signs. (UN1952 GERSS, 15). Turkey adopted the American system but would later take up the GERSS approach.

Japan's traffic control development is at a more advanced and developed level than much of the Asian continent. Japan's approach to traffic signals and signs mirrors its approach to industrial development: a selective and judicious borrowing of ideas and practices with a subsequent altering through the crucible of Japanese experience, culture, and indigenous development.

Japan's first substantial sign system began in 1922. (PICHSS 1972, 28). That system made considerable use of OBS. Most of the signs were either warning or guide signs;

and included the dual-sign approach of graphic symbol and word message. OBS was widely employed in UK and its possessions and affiliations but this is the first usage of OBS outside of that orbit. (PICHSS 1972, 28).

In 1942 Japan promulgated a new ordinance for signs. (PICHSS 1972, 28). This expanded system added "prohibitory, regulatory and instruction signs" to older forms. The German sign model was prominent in this revision. And, in turn, Germany's system was influenced by European work in sign techniques and applications. This can be seen in the choice of color meanings and basic symbols adapted by Japan which resembled those of the 1931 Protocol. (PICHSS 1972, 28).

Japan revised the ordinance in 1950. This revision was in accord with UN 1949 Protocol. (PICHSS 1972, 28-29). However, not all of the UN provisions were adopted: some US influence was also present. Japan adopted a five-part division of signs: guide, warning, and prohibitory, instruction and indication (the last three are regulatory signs). Regulatory signs followed UN symbols in most instances while the American system served as a pattern for warning signs. Guide signs followed an original pattern. However, a variety of guide signs were both more complex, and less adequate than those of the 1942 revision. (PICHSS 1972, 28-29).

Among the more curious international agreements on traffic control devices is that of the Central and South Africa Transport Conference, Johannesburg 1950. The Conference included Southern Africa, much of Central Africa, and parts of north-central Africa. But only one of the government participants was an African-based nation (The Union of South Africa with a minority government). Other participants included several European nations and a variety of dependent states. The U.S., and the International Bank for Reconstruction and Development were also in attendance. (CASATC 1950).

CASATC signs incorporated UN 1949 sign shapes and symbols, but in conjunction with the OBS style of

danger warning signs. (CASATC 1950, Ap III; UK MOT Broadside). Each sign unit contained a Protocol triangular-shaped sign displaying OBS danger warning colors of yellow and black. (CASATC 1950, Ap III, Sch I, 83). The source of the two-part sign concept is not given in CASATC, but presumably originates with OSB sign concepts. (CASATC 1950, Ap III, UK MOT Broadside). CASATC is included in GERSS where it represents a third approach to signs. (UN 1952 GERSS, 17).

CASATC danger signs were triangular-shaped with red border and white ground. A square or rectangular-shaped plate below the main sign displays specific symbols for the danger in question. Prohibitory and mandatory signs formed a single group. Many displayed a circle with red border and white ground with the adjoining plate rectangular and yellow. Informative signs included not only informative signs as such, but also warning signs. Many of the actual information signs are similar to UN 1949. (CASATC 1950, Ap III, Sch 1, 2).

Traffic signals were listed under a heading of Traffic Light Signs but they were actual signals. Standard signals were termed "robots". "Flash Lights" are red and yellow flashing signals. Pavement markings are listed under road markers. (CASATC 1950, Appendix III, Schedule 1).

#### c) The 1949 UN Conference: The Protocol

The 1949 UN Conference and resulting Protocol was the first UN effort in TCD and, to some degree, were global in expectations and scope. The Protocol provides both an extension and expansion of earlier attempts at international traffic signs systems and underlies many current systems. It represents one of the two major currents in global traffic sign language.

The 1949 Protocol might have provided the basis for a global system of signs but this failed to occur. Instead, the 1949 Conference led to a concretizing of existing divergent approaches especially for danger warning signs. European nations represented a substantial part of independent

nations in the late 1940s. and, not surprisingly, the European position was strongly reiterated in the UN Protocol. The Protocol was in the vein of 1909-1926-1931-[1938-39] agreements and those earlier agreements were all European in basis and outlook. (UN 1952 GERSS, 7). The Protocol, however, failed to gain sufficient ratifications to achieve official status though heavy usage of its provisions did take place.

The end result of that Conference was a bifurcated statement: a vague and general outline of good intentions (placed in the Conference documents) that was sufficiently bland and vague to be agreeable to all, and a very specific European-based Protocol acceptable to only somea portion of the participants. (UN 1952 GERSS, 1952, 2-3). The 1949 Conference authorized a further study by experts in order to achieve the yet elusive goal of a more global system of signs. The study, that of GERSS, was held but no global system was forthcoming.

The 1949 Conference divided signs into categories that continue to form current sign practices: "Signs giving definite instructions," danger warning signs, and informative signs. (UN 1949 Protocol, 79-80). Each form of sign was to have a specific shape but not a specific or distinctive color. This was contrary to the American system in which color is a major factor. (UN 1949 Protocol, 80; US MUTCD). All warning signs and the prohibitory segment of "signs giving definite instructions" share the same border, ground, and symbol colors. (UN 1949 Protocol, 82, 91). The 1952 Draft Convention retained it for nations using Protocol-style signs. (UN 1952 GERSS, 39, 54; Shoaf 1971, 61). Part G, *International TCD*, provides a summary of the message aspects of the various types of signs.

The 1949 Protocol contains the first coverage of traffic signals in an European-influenced document. The documents provide for a three-color system of red, green, and amber, and a two-color system of red and green. In the second case a combination red and green signal can serve the purpose of an amber signal. Flashing amber is permitted though no mention of flashing red is made except for

railway crossings.

The first mention of pavement markings in an European-based safety publication is also in the Protocol. Though the provisions are not extensive. This may be understandable since the publication was a pioneer effect. Provisions include lane markings and edge reflectors for a variety of purposes are offered in various colors,(UN 1949 Protocol, 111-112). OECD notes that regularly employed pavement markings began outside the United States in Germany and UK in 1939. And not until 1946 in other nations. Delineators began use also in 1946 and frequent use of raised pavement markers began in about 1950. (OECD 1975, 13).

### 3D2 Traffic Control Devices: New Directions & Changes, 1952-1968

#### a) UN GERSS 1952

Another attempt was made for a global system of traffic control devices not many years after UN 1949. That effort was headed by the Group of Experts on Road Signs & Signals (=GERSS) of the UN. Its goal was that of 1949: to unify road signs and signals internationally. UN 1949 had updated the "European System" though there were other approaches to sign including the "American System." (UN 1952, GERSS 1, 7-8).

Differences in safety aids between 1949 and 1952 are found mostly in signs. There were fewer divergencies in pavement markings and even less in signals. GERSS was concerned how to accomplish large-scale changes since both systems (European and American) were well-entrenched. Changes were needed if uniformity was to be achieved since neither system had all of the desired features. (UN 1952, GERSS, 9-12).

A uniform system depended in large part on unifying danger signs. Tests on danger signs were held in six regions of the world in 1951. Practical results indicated that the diamond-shaped signs with black symbols on yellow

background were to be preferred since that permitted larger symbols and two color patterns, instead of three, was cheaper. Warning signs could be in three patterns for a transition period: Protocol, CASATC, American. But the diamond-shaped form was to be the preferred form. The stop sign was also to be from the American system. The oblique bar from Protocol was to take on global usage. (UN 1952 GERSS, 17-22).

Traffic signals were to include a flashing signal in amber ("proceed with caution") and flashing signal in red ("Stop then proceed with caution"). However, UN 1968 was to veto that signal. Pavement markings for GERSS were to include several categories including longitudinal, and transverse forms. (UN 1952 GERSS, 62-71).

The 1952 Draft Convention avoided the pitfalls of 1949. But this expertly researched effort was never presented at an international conference though the document was open for signatures. In the view of some, the refusal of the U.S. to sign the document resulted in the failure of GERSS. Provisions of GERSS were borrowed, adapted, adopted by various nations and groups. That selective usage increased uniformity but it also contributed to fragmentation. 1952 may have been the last chance for a relatively uniform system. UN 1968 concretized the dual approach already existing. (Part F).

#### b) I.A.M., ECAFE & Changes, 1952-1968

Between GERSS in 1952 and UN 1968 a variety of systems in diverse areas of the world, including Asia and the Americas as well as changes in existing national, regional groupings took place. This welter of change does not have a readily coherent character though there is some rationale to it; it is not entirely an scatter-shot series of events.

A relatively early effort is the *Inter-American Manual of Traffic Control Devices* in the Americas. Actual beginnings can be traced to the 8th Congress of Pan American Highway Congress at Bogota, 1960. A Technical Com-

mittee was formed for the project, and a sub-committee appointed to construct the *Manual*. During a series of meetings various components of were assembled. The *Manual* was approved in principle in 1968 by PAHC though completed, published in 1967. ("Project," 1; PAHC 1968, FR, 6).

IAM has a composite nature. It contains elements familiar to both Protocol and to American systems. Some portions, such as pavement markings, are very similar to MUTCD. Regulatory signs are also similar though IAM employed many more graphic symbols; newer editions of MUTCD have also moved to greater use of such symbols. Much the same can be said of warning signs. Guide signs include both Protocol and American elements. One component of these signs is reprinted from Protocol. The *Manual* improves upon both UN and US ideas though it continues to show affinity with hemispheric practices. It also precedes the MUTCD in widespread employment of graphic symbols. (IAM 1967, 2-4, 44-51).

UN 1952 GERSS had an impact on various TCD systems in this time. The most notable is probably the ECAFE (Economic Council for Asia and the Far East later ESCAP Economic and Social Council for Asia and the Pacific). The ECAFE TCD code was promulgated at Saigon, 1964. Provisions are very similar to GERSS. In fact, wording is often identical and meanings are similar even with variant wording. ECAFE added red borders to warning signs contrary to GERSS practice (though GERSS tested the idea and found such borders did not improve legibility). Stop signs were in circular as well as octagonal shapes. Informative signs were virtually identical to GERSS. ECAFE permitted two-color signs. Pavement markings displayed similarity. (UN ECAFE 1964 Code).

Several smaller-scale versions were also in use. Turkey may have adopted GERSS for a time but the 1975 Turkish code indicates close conformity to UN 1949 and 1968. Ireland implemented GERSS and seemingly is the only European nation to do so. Ireland employs UN style information and regulatory signs but warning signs follow

the American pattern and those of GERSS. A Central American system was also influenced by GERSS though many signs were indigenous to the Americas. (Part E).

The Old British System was a major sign system for many years. It had a distinctive quality and proved to be a workable approach to signs. The United Kingdom decided to switch to UN 1949 before UN 1968. The growth of tourism required signs with graphic symbols and UK thereby joined the continent of Europe in displaying uniform signs. (Usborne 1967 *TE*, 20-22).

The Nordic Council began work in 1960 on a common traffic code. It does not differ greatly from international systems. This is, in part, because the Nordic Council was involved in European efforts to revise UN 1949. A basic concept in their work was the equation "Shape plus Colour plus Symbol equals SIGN." This conceptualization brought about a coherent and rationale approach to working out signs of whatever form. (G & L 1967, 50; Norway 1980 *FOOT*, Kap. VIII). One might note, however, that shapes and colors in themselves also constitute symbols. Symbols in the Nordic work largely refer to graphic symbols (geometric and other designs).

Canadian provinces included some five different approaches to traffic control devices. The US MUTCD was a major influence on these systems though not an exclusive influence. Between 1956 and 1960 work on a Canadian Manual was undertaken. It incorporated many graphic symbols which reflects a growing practice. A singular development was the use of green circles (annular rings) that denoted a positive message. Red circles employed to denote negative messages were a commonplace but not the reverse of green for positive outside Canada. (Finnbogason 1963 *TE*, 24-27).

US MUTCD 1948 and MUTCD 1961 both emphasized the use of word messages. Graphic symbols were infrequent and mostly in the future. Stop signs, which had been yellow with black letters, became red with white letters. That version of the stop sign is an often employed sign

in much of the world. (US MUTCD, 1948, 1961).

UN 1968 would move the world toward a greater degree of uniformity in TCDs. But it would not be a simple system of massive uniformity. Both the work of the council and long-entrenched practices in many parts of the world would preclude a highly integrated single system.

### 3D3 Global Traffic Control Devices: UN Conference 1968 & Afterwards

The UN Conference on Road Traffic (1968) had its beginnings in 1963. It was to be a revision of the 1949 Conference on Road Traffic and Protocol on Road Signs and Signals. UN 1968 included delegates, observers, and representatives from 100 nations, as well various groups. One pre-conference draft convention was completed in 1965, and a second in 1967. The second was noticeably at variance with the first. That second draft was substantially influenced by ECE and ECAFE. The final draft was completed in 1969. (UN 1969, RSG, 3, 6, 10).

There were many changes between the 1965 and 1967 drafts. The new draft allowed usage of either triangle or the diamond but there was a "slight preference to the triangle." There were two forms of stop sign (European, American) and again there was preference for the European form. The American stop sign narrowly missed approval in the Conference. The desire for uniformity was expressed by various delegates. A second view wanted member-states to indicate which warning, stop or yield models they preferred. (UN 1967, DCRSS, UN 1969, CORSS).

A very serious problem occurred with red oblique bars. The bar, a red diagonal bar across the face of the sign, denotes prohibitory behavior. Such signs also have a red border. UN 1968 allowed a deletion of the bar yet the meaning of prohibition remained the same. However, some prohibitory signs require the bar and GERSS 1952 employed signs with red borders (without the bar) to designate mandatory behavior. This resulted in signs meaning no for some nations while displaying a reverse

meaning of yes for other nations. Canada later added a green border for mandatory signs denoting a required action. (UN 1969, CORSS; Zuniga 1965, 5).

Neither the uniformity camp or the "pick and choose camp" seemingly were able to simply accept two streams of TCDs. A delegate from Canada, Lasalle, offered a number of observations which illuminate how Conference attitudes were formulated and expressed. Lasalle noted for future conferences that there are "two different systems of TCDs in the world." Two systems not one. Two systems not a smorgasbord from which one selects various elements. Lasalle defined TCDs as "road signs, traffic signs, and signals and road markings set up permanently or temporarily to regulate road traffic." His attempt to gain acceptance of the term TCD had earlier been rejected. However, the Conference on Road Traffic had included it. He also noted that providing for variants weakens the UN system; that allowing two systems with few variations would be preferable. Continued seeking after total uniformity undercut regional systems that worked well. (UN 1969, SR 1st-8th).

Traffic signals were treated at less length in 1968 than in 1949. Signals with simpler messages were largely established before either UN Conference took place. Some changes were made. Amber could be exhibited at two different points in signal phasing: not only after the green but after the red. UN 1965 DCRSS tied color and shape together: red to be circular, amber to be triangular and green to be square. This provision was later dropped. The "Single Flashing Red Light" was dropped from UN 1967 DCRSS. A single red light is permitted at grade crossings contrary to western hemisphere practice requiring two. For visitors outside the Americas a single red light denotes railroad crossing not an intersection. Despite its rejection, widespread usage of a single flashing red beacon continues to be employed in a variety of nations down to the present. Flashing red lights for level crossings, moveable bridges and other uses continued. But not at intersections. (UN 1967, DCRSS-NSG; UN E/3999).

Traffic markings were passed over in early 20th century European-centered systems. They are included only briefly in UN 1949 with only three forms of road markings. The 1968 Conference is the first extensive treatment in global setting. Traffic markings include longitudinal markings (including traffic lanes), transverse markings (e.g., stop lines), pedestrian markings, and standing and parking regulations. Changes in drafts in 1968 included replacing the term road surface markings with carriageway markings. Road markings remained a secondary term. The term traffic markings does not appear. (CRICMV 1909; ICRMV 1926; LN 1931 CCURS, UN 1949, 111-112; UN 1969, CORSS).

TCD systems are not concretized in one time and one place thereby lacking the possibility of further change. And various changes did occur in the first years after UN 1968. In Europe ECE opted for the European-style of danger warning signs. But they chose instead the American form of stop signs. A color code for road markings was established. Railroad crossings displayed two red lights which parallels the western hemisphere and avoids confusion with single flashing red lights at intersections. (ERCR-TSS, UN ECE 1971, UN ECE 1977).

The US added the European circular "do not enter" sign from Europe (red with horizontal white bar). Gradually the U.S. moved to a fuller use of graphic symbols. Yield signs followed the move to the red and white of stop signs. Flashing red beacons were retained. The *Inter-American Manual* (1981) retained the older color format for yield and stop signs (from 1967). Graphic signs were heavily employed in 1967 and continued to be so employed. (US MUTCD 1971; Shoaf 1971, 60-61). Canada offered a variety of new ideas of significance. The most important may have been the green annular rings for mandatory signs. These contrasted with mandatory signs with red rings and prohibitory signs which were sometimes accompanied by a red oblique bar (and sometimes not). Canada retained the red ring and oblique bar for all prohibitory signs. Canada added tab signs, and checkerboard signs to note significantly sharp changes in alignment. (Canada UTCDC 1976).

## CHAPTER FOUR

### RADIO AIDS, 1904-2000

#### 4A Radio Nav aids: Early Days & En-Route Nav aids

##### 4A1 Introduction to Radio Nav aids

At the beginning of the 20th century (1901) radio aids were unknown though experiments in radio were already underway. Visual aids dominated that era with sound signals serving as a vital augmentation. Vast lighthouse optics and enormous fog horns were a staple of that world. In the 20th century radio aids would first initially and tentatively enter upon the navigation scene then very quickly become a vital element and -- before the end of the century -- eclipse and replace many long-enduring visual and acoustic aids (and for that matter, even some early radio nav aids). A point was reached late in the century when one aid, GPS and its augmentations (such as DGPS) promised -- or threatened depending on one's view -- to affect every dimension of navigation aids including road and rail signals.

Radio Nav aids are substantially marine and aero aids while road and rail aids though heavily influenced by electronics are largely visual (with limited sound forms). Electronics has an increasing role for railways through control systems though less so in actual signal systems for crew usage. GPS, however, is beginning to have an influence on railway operations and here signals in some form may be involved. Overall, aero aids are most affected by radio; hence a large portion of this chapter focusses on aero aids though marine aids are not insignificant. GPS, DGPS and allied systems arrived late in the century and, while their influence is important, their greatest role is beyond the period of this study: after the year 2000. Rail and road radio aids are therefore relatively minor elements in this chapter.

Short and shorter-range en route aids, such as Radio Beacons/Non-directional Beacons are vital to navigation as

are approach/landing aids. Yet Hyperbolic Aids over more than 60 years have blossomed forth into a variegated array of forms well beyond other types and that constitutes a large part of all radio aids. This results in half of the chapter centering on those forms. The many pages devoted to hyperbolic aids do not negate the importance of other forms whose quantitative coverage is less.

The chapter begins with the first years of the 20th century. It continues with various, and often older, short range en route aids. Hyperbolic occupies a second sub-chapter ending with smaller segments for satellite aids and approach/landing aids.

##### 4A2 Early Days: Radio Nav aids Before 1920

Radio communication began in about 1879 with experiments by D.E. Hughes in London. The work continued in the last years of the 19th century. The first ship-to-shore communication may have occurred in 1895. Marconi, among others, worked on wireless communications early in the new century. By 1905 he had patented an aerial system coupled with a receiver that could approximately ascertain the direction of signals from a transmitter. (Kendal 1991, 313-315).

Soon after (1907) The Telefunken company in Germany created an aerial system with the transmitter adjoining the aerals known as the Telefunken Compass. This is the first form of the rotating beacon. A transmitter emitted (radiated) a beginning signal to a central radiator. Transmissions on 32 aerals (for the points of the compass) were arranged around a central aerial. A navigator with stop watch could determine bearing by stoping the stop watch at the strongest signal. The system was employed during World War I. The accuracy of those early aids is uncertain. Kendal. notes this is the ancestor of all rotating beacons since it manifested two basic characteristics to be found in all air navigation systems: limitless users for the signals (since the aircraft had no role in emitting signals), and aircraft equipment did not affect the transmission of bearing information so the state of airborne equipment

could not alter received data. (Kendal 1991, 315; Williams 1992, 187).

The core idea of the Lorenz system known as the Course Setter was also inaugurated in 1907. Two aerals produced signals that were "A" and "N" in Morse code. If on course both signals were received equally; if one signal received that denoted off course. Williams notes that a Direction Finding (D/F) airborne unit could employ it as a non-directional Beacon. Work continued through World War I but the project was terminated. Equi-signals heard on the ground could not be adequately heard in the air. The A/N transmissions suggest the radio range of the future. (Williams 1992, 187-188; Kendal 1991, 315-317).

Kendal notes that the Course Setter with its interlocked signals was the precursor of Lorenz and SBA (Standard Beam Approach) systems and eventually ILS (Instrument Landing System). The Bellini-Toss D/F Systems (substantially airborne) had a transmitting form: the Radio Range. (Kendal 1990, 317).

An additional navaid was the Wireless Lighthouse. While substantially a marine aid it was also employed by aircraft and included in Kendal's survey of aero navaids. Marconi carried out trials from 1916 to 1921. This resulted in the Wireless Lighthouse at Inchkeith Island. The aerial array slowly revolved and thereby transmitting one letter per bearing. Two minutes were need for a complete revolution and the ship's radio operator could determine the ship's bearing once per minute. The strongest signals indicate bearing from beacon to ship. Because of the faster speed of aircraft, the aircraft travelled some distance during the time it took to gain a bearing reading. The aid transmitted on 50 MHz which is an early use of VHF. (Kendal 1990, 318; Williams 1992, 187). The US Bureau of Standards worked on direction finding receivers in the years 1912-1916; that work evolved into work on transmitters.

Scheller (of Course Setter fame) proposed an additional system which was to become the Radio Range.

His idea consisted of interlocked signals transmitted from aerals thereby producing a figure-of-eight pattern. This resulted in four tracks (to/from transmitter). Scheller applied for a patent in 1916 for a version that called for movement of the tracks via a goniometer rather than actual movement of the aerals. (Kendal 1991, 318). Solberg notes that the wire in an antenna (or aerial) can be shaped and the antenna will transmit the maximum amount of energy according to the plane of the wire's shape. (Solberg 1979, 133).

#### 4A3 Point-Source Aids

There are probably few safety terms that can be agreed upon unanimously. Point-Source Aids is no exception. It can refer to aids that consist of a single station for transmission and which do not create lines of position that can lead to determination of position of receiver. Though in some instances transmission can be discerned from two separate units thereby creating an intersection of transmissions which determines position. In this historical survey Point Source Aids refer to radio ranges and associated Beacons; non-directional Beacons; and VOR and associated aids. These aids are placed within a context of en-route aids. Final approach & landing aids (of a beacon form) are placed in a seperate segment (though those beacons overlap with point source beacons.

##### a) Radio Range

Scheller's concept of equi-signal was developed further in the US in 1924. "Crossed loop aerals" thereby created four courses with transmissions in MF. This aid was termed the radio range beacon or often simply radio range (four-course radio range in Komons 1978,154). US Army Engineers in the late 1920s made modifications in the radio range which resulted in an ability of the beacon to be programmed in virtually any needed direction. The radio range became the standard navaid for the US until after World War II.(Kendal 1991, 318-319). However, Solberg notes it was the US Signal Corps that requested the US Bureau of Standards to develop an aural beacon rather than

the US Army Engineers directly. (Solberg 1979, 133). And this occurred in 1920 according to Komons (Komons 1978, 154). Komons notes the basic system was formulated in the years 1920-22 (with major European influence) then the Signal Corps worked on it 1922-1926 with additional changes by the Bureau of Standards 1926-1928. (Komons 1978, 154).

The original transmitter for the radio range was aboard the Lighthouse Tender Mary (at Washington Navy Yard). It employed two loop antennas with one antenna's strongest signals in two directions (in opposite directions) while the second antenna duplicated transmissions but at right angles to the first antenna. This created four quadrants: two for one signal, two for the other: Morse code "A" and Morse Code "N". When on the line between "A" and "N" both could be heard distinctly. Army Air Corps developed the system to a point where A and N in equisignal zone was a hum. (Solberg 1979, 133-134). Whitnah notes that when A and N merge the resulting message is a T. (Whitnah 1966, 71).

There were problems of propagation with MF in the radio range which brought about further work by the US Department of Commerce. The first effort resulted in a two-course beacon (based on Lorenz) followed by a four-course beacon. The frequency employed was 63 MHz. Other problems arose which, also, were resolved. The beacons worked well on a straight course but abnormal conditions reduced effectiveness. Frequency was increased to 125 MHz but the signal strengths varied especially over mountains. While various problems were resolved the beacons could only give four possible routes. This resulted in demands to examine an improved rotating beacon. Kendal 1990, 319-320; Williams 1992, 190).

There were several supplemental markers that were associated with the radio range system. These included Z-Markers, M Markers and Fan Markers (hyphens are generally included with Z-Markers but not with M Markers). Z-Markers were a supplement to the cone of silence. It enabled pilots to definitely determine position

over radio range system. The cone of silence (a zone free of radio signals at the point where signals were being transmitted) was a kind of negative indicator of the presence of the radio range station but it was subject to error. Experimental Z-Markers were introduced in 1934. They transmitted on 75 megacycles and were the first aero navaid in U.S. airways to employ VHF signals. The signal activated a flashing light on instrument panel of airplanes; an aural indication was also given. (Komons 1978, 338).

Fan Markers were an extension, outgrowth of Z-Markers. Fan Markers replaced "M" Markers which were a low power aid of limited strength and range. (Komons 1978, 340). Fan Markers emitted signals in the VHF spectrum range. The name came from the shape of the signal. Substantial work was underway on the marker in mid-1930s. After success with experimental markers beginning at Hunter's Point VA it entered regular service in 1938. (Komons 1978, 340-341).

Other work on approach aviation systems in 1930s included a system by Lorenz that offered azimuth guidance and vertical guidance to approaching pilots. These functions were accompanied by three marker beacons that offered distance-to-run-information. Standard Co (UK) developed the Lorenz system which became known as Standard Beam Approach (SBA). This was the standard approach aid for RAF not only during World War II but afterwards until ILS in the 1950s both for military and for civil aviation. (Kendal 1990, 321).

#### b) Beacons

Marine sources speak generally of marine radio beacons which includes a variety of forms. Aero sources most often refer to non-directional beacons which includes a single form. non-directional beacons (often known by the acronym NDB) can possibly serve as an overarching term though it is less often applied to marine beacons. Beacon serves as a general term for this coverage since it encompasses the full range of these aids without suggesting a specific type of aid. Fixed non-directive marine beacons

is an older term that describes the character of the aid. (Keen 1938, 464). The Database in this Series discusses these and related terms.

Marine Radio Beacons began in the U.S. in 1921. NDB (for aeronautical uses) began in about 1930. International Telecommunications Convention established standards for maritime and aeronautical radio beacons in 1932. (Keen 1938, 462-463). The US Bureau of Standards experimented with direction finding in 1917 with a direction finder installed on the Lighthouse Tender Tulip and the received signals came from a transmitter at Navesink Lighthouse, NJ. The work appeared to be promising but was disrupted by the advent of World War I. Tests resumed in 1919. During the renewed tests transmitters were installed at three lighthouses in Chesapeake Bay with Radio Direction Finder (RDF) on the Lighthouse Tender Arbutus. Improvements continued in the next year and prototype transmitters were installed on two Lightships (Ambrose, Fire Island), as well as at Sea Girt Lighthouse, NJ. These became the first operational units of US Marine Radio Beacon Service. Diamond Shoals Lightship (LS), NC, and San Francisco LS joined the service in 1922. (O'Brien 1983, 4-5).

The original names for what became known as the radio beacon were radio fog signal, and wireless fog signal. The name clearly indicates that the radio beacon acted as a supplement to sound fog signals and suggests it was not a full-time aid. At first the radio beacon transmitted continuously in foggy conditions though there were also limited periods of operations in clear weather. Those limited hours in clear weather led to regular service in clear conditions. And the term radio fog signal faded out. (O'Brien 1983, 4-5).

The first transmitters were employed in 1924 at Ambrose Lightship. An older form of transmitter was gradually phased out and ended service in 1930. (O'Brien 1983, pages 4-5, 8). Frequency at first was 300 kHz. This was modified by the International Radiotelegraph Conference in 1927 which decided on a frequency band of

285-315 kilocycles. Class A Radiobeacons could be heard up to 200 miles; B 100 miles and C, 20 miles. Automatic radiobeacons began service in 1928. Distance finding beacons (radio beacon and fog signal synchronized) began in 1929 at Cape Henry, Virginia. (O'Brien 1983, 8).

The chronology for aeronautical NDB while not as precise as for marine forms can be constructed. Kayton 1990 notes three events in 1929: Radio ranges (four-course), direction-finding beacons, and vertical marker beacons. (Kayton 1990, 229). Presumably direction-finding beacons are NDBs. By 1930 several DF beacons were in service. More than 30 radio range stations were in operations by 1930. (CAA 1945, 12). According to a UK source, Kendal, the radio range began in mid-1920s and was joined by NDBs. (Kendal 1990, 329).

By the end of the 20th century the place of NDBs had declined and in some instances to a drastic extent. Clausing in 1987 offered the view that NDB's "virtues" will preclude its complete extinction. Its longevity centers on its low-cost simplicity. Few radio aids have lasted the greater part of the century. (Clausing 1987, 78).

NDBs have been of several forms. Compass Locators are associated with ILS. NDB serves as the main aid at the approach facility for some airports. Historically NDBs had a major en-route navigation role. But en-route beacons have become less common in the U.S. save for Alaska. They remain a primary aid in various parts of the world. (Clausing 1987, 79). Other NDBs are coastal beacons which are mostly marine radio beacons but that is a largely obsolete role since most existing radio beacons now perform a DGPS function. (FRP 1990, 3-31, FRP 1999, 3-24). Marine forms broadcasted a Morse Code message that could be identified with a specific beacon. (Maloney 1985, 446).

Federal Radionavigation Plan (FRP)1990 forecast a relative stability in NDBs through the 1990s with a gradual decline in the early 2000s. The one exception were DOD beacons which were to be sharply less by 2003. However,

FRP 1999 noted that nearly all USCG radio beacons were now employed in a DGPS role. Only a very few traditional beacons were still in service and their days were numbered. (FRP 1990, 3-31, FRP 1999, 3-24)

### c) VOR, VOR/DME, VORTAC, TACAN

Acronyms are common in government-related operations and that is especially true here. VOR (VHF Omnidirectional [Radio] Range). VOR is employed more often than the full name. DME is an acronym for Distance Measuring Equipment. TACAN is an acronym for TACTical Air Navigation, a military aid. VORTAC combines two acronyms. The acronyms dominate the literature and will be heavily employed here.

Casabona dates the origins of VOR to 1928. In a sense the remote origins of VOR can be traced to the early 20th century. Bauss notes that omniranges began in 1908 (the Telefunken Kompass) though that early form was in low frequency. Actual work was carried out at Bell Telephone Labs from 1928 to 1930. (Englund, Evans, Greig researchers). It was disrupted by the Depression but restarted by D.G.C. Luck in about 1937. CAA carried the work forward from 1940 through World War II. The completed project went to RTCA in 1945. It was accepted by PICA0 in 1946. (Casabona 1959, 26-44, Bauss-Barner 1963, 43). CAA had considered using a rotating beacon at HF in 1936. But by the late 1930s VHF was undergoing increased usage and CAA switched to that frequency. Other changes in the beacon led to an omnidirectional antenna. Further experiments and research led to an embryonic VOR somewhat similar to current form. (Kendal 1990, 320).

Since 1944 the CAA worked to perfect VOR but the first VOR-equipped air route (Victor Airway) was not ready until 1950. VOR is sometimes dated to 1946 ; this may refer to VOR in itself rather than as an organized system. (Robson & Thomas 1971, 259). But in just two years there were over 45,000 miles of VOR airways and nearly 400 VOR installations. Some problems remained including radio interference from FM radio as well as a

question of inadequate precision. By 1951 various problems were largely resolved. By mid-1951 a substantial degree of accuracy was achieved for both azimuth and distance information. (Wilson 1979, 229-230).

The VOR system was well beyond the older radio range system in value. But VOR displayed limitations. For example, low elevations and mountains reduced capability since VOR was a line-of-sight system and traffic was formed in narrow channels creating possible congestion problems at intersections. The range of 100 nm was relatively limited. (Taneja 1987, 31).

VOR provided direction information but not distance information. Frequently VOR was combined with a second unit known as DME (Distance Measuring Equipment). DME can be traced back to radar range research and developments during World War II in UK. However, unlike those radar systems cathode rays were not used and "natural echoes" were absent. Numbers and "artificial echoes" were employed instead. (Robson and Thomas 1971, 268). Grover notes that DME is an advanced form of the Rebecca/Eureka System (R/E). DME like R/E consisted of a transponder on the ground which could be activated by an "interrogator" in an airplane. The air portion transmits a pulsed signal to the transponder which "recognizes" the signal and transmits a response with needed information. (Robinson [RDF] 1985, 37-4).

In 1955 a long simmering controversy bubbled over in US aviation circles. CAA began installing VOR & DME soon after World War II. U.S. Navy had problems with VOR-DME because of space limitations on aircraft carriers. As a result the Navy contracted with Federal Telecommunications for work on a more usable system in 1947. By 1951 the new project was called TACAN for TACTical Air Navigation. Air Force shifted its endorsement to TACAN. The new system was viewed as more flexible, accurate and more integrated (direction, distance functions in one unit). The hoped for common system became instead a double and diverging track. (Rochester 1976, 74-76).

There were claims by the military and CAA that the systems were not a duplication. However, TACAN and DME were in the same frequency band. Technical experts wanted secrecy removed from TACAN in order to attempt to work out the issue of lack of compatibility but the military refused. The two systems continue to develop, expand separately. In 1953 the military removed the secret status of TACAN (de v. Hauteville has 1955). Apparently the military had begun to understand the additional expense of two systems and their lack of compatibility. In addition, by making TACAN visible they hoped to claim superiority for TACAN. A group of experts narrowly favored TACAN. But CAA and a civilian group questioned the reliability of TACAN and its higher costs as well as the unclear decision of the group of experts. Various maneuverings took place. Air Transport Association (ATA) decided to favor VOR and DME in contrast to its previous stance ATA questioned TACAN's laboratory results as well as the military handling of the crisis. The situation drifted in limbo until a compromise of sorts was achieved. (Rochester 1976, 74-76). That compromise was to add TACAN to many VOR sites thereby creating VORTAC. (de v. Hauteville 1963, 59).

TACAN consists of a single unit that integrates direction and distance dimensions. The TACAN idea was also adopted by the British Navy. TACAN was primarily for military use though Grover in 1957 thought it might be superior to VOR/DME overall. (Rochester 1976, 74-76, Grover 1957, 119-120).

#### d) Radar Aids

Radar aids are "tacked on" to Point-Source Aids as a matter of convenience. It can be debated to what extent they are a point-source aid. While most radar is primary there is a secondary radar and usually safety aids are of that form.

Radar is substantially a British idea. The idea began in the 1920s with substantial development by the mid-1930s. Much of the impetus for radar was the threat of the

impending crisis of World War II. Because of the need for early and rapid development of radar the English government and research efforts were given over to the US for further development and application. (Williams 1992, 212). Radar nav aids became a part of radar development at an early date.

Secondary radar employs a transponder (a transmitting unit) that is attached to a defined location. When triggered (or interrogated) by a ship or aircraft transmitter the transponder becomes activated and emits a signal. (USNOO1969, 222).

Grover notes that events leading to secondary radar came very soon after primary radar. The core idea focussed on the notion that a radio transmission could activate a receiver which, in turn, could trigger a transmitter that responded to the original interrogation. And this second transmission could be arranged to carry a coded identification signal. (Grover 1957, 74-75). Smith notes that the pulse appears on the radar screen and the airborne equipment could achieve determination of position by the single incoming pulse transmission. (Smith 1948, 11).

Williams notes the development of IFF systems (Identification of Friend or Foe) in World War II that consisted of radar pulses which activated coded return messages. This is the beginning of transponders (and of secondary messages). The original form were not nav aids though the idea and technology were transferred to nav aids. (Williams 1992, 214).

Early forms of transponders were part of search radar and the early beacons went under the names of ASV and AI Beacons (ASV="detection of surface vehicles from the air; AI=air interception") which refer to primary radar but altered for a secondary purpose. (Smith 1948, 11). The first transponders were IFF units that had been modified for the new nav aid purpose. (Williams 1992, 215).

The ground station is referred to as responder or more often, a transponder beacon (radar responder, radar

transponder beacon and simply radar beacon are other names employed; racon is the dominant term at least for maritime use). Grover speaks of the beacon as being dormant when not in use. It has to be triggered in order to operate. The receiving mechanism can carry out computations that lead to distance information. (Grover 1957, 75).

A well-known early form was the Rebecca/Eureka system. It began as a World War II navaid but later moved into civil aviation. Rebecca was the interrogator unit while Eureka was the ground responder or transponder. (Grover 1957, 76-77). Eureka beacons were designed to interface with Rebecca equipment. Early forms were employed for supply work during the war. (Smith 1948, 19).

Transponder beacons extend down to the present day. However, that original form has been augmented by other forms of radar systems including those for marine navigation. One form is the Ramark or Radar Marker. This is a radar beacon that transmits continuously and does not require triggering. It is non-directional and indicates bearing when the pulse signal is picked up by a ship's radar screen. (USNOO 1969, 206, 259).

Primary radar is not entire absent from navigation aids though indirectly. Primary radar is more adept at sorting out targets on the screen when of specific shapes. This has led to development of radar reflectors on buoys and some shore stations. These reflectors, dating back to at least the mid-1940s, display one of several geometric shapes formed in metal. They are commonly employed and enhance the ability of shipboard radar to ascertain the object, and to some extent, location. (Wylie 1976, Ch 11).

## 4B Hyperbolic Aids

### 4B1 Introduction

The "pre-history" of Hyperbolic Aids begins in about 1904 (which is also approximately the beginning of all Radio Aids) and extends to the late 1930s. Blanchard notes that the theory existed from about 1911 but the necessary technology did not exist until the 1930s. (Blanchard 1997, 161). Hyperbolic Aids in an operational sense begin in about 1940 and extends into the 1960s (at least in a ground-based sense). This coverage focusses on individual aids from 1940 and extends into the second half of the 20th century; cursory attention to the origins and early developments is included.

Aids of an hyperbolic nature lacks an encompassing term. The T-M Database employs Hyperbolic Aids with Hyperbolic Navigation Systems as an alternate and adding "radio" to the later term provides a variant of the alternate (Hyperbolic Radio-Navigation Systems). That term and the simpler Hyperbolic Aids may provide short and long names for this coverage. Database Ii and Iiv provides a review of terms, meanings and references for those terms.

Hyperbolic Aids (as well as variant forms of that term) encompass a broad range of systems. This is the largest sub-division (both aero and marine) within Radio Aids. Such aids are frequently long-range or approach long range capability. The name stems from the geometric term of hyperbola. Hyperbolic lines in navigation are lines of position (LOP) that intersect and denote position of a vessel. These lines are produced by various types of transmission equipment and when received can be translated into a moderate to a very precise determination of the receiving vessel's position. Hyperbolic systems differ in a variety of ways, but the production of hyperbolic lines from multiple stations thereby creating intersecting lines is a constant (or nearly so) of the various systems. Some systems employ pulsed signals in which measurement is taken of the intervals between pulses. While other signals emit continuous waves in which the wave phase is

measured. (T-M Database II, liv; Blanchard 1991; Fifield 1980, 165).

W.F. Blanchard offers this definition: "a hyperbolic system ... [is] one which uses comparatively widely-spaced sources of radio energy acting in concert in order to produce navigational cover over a large area in terms of hyperbolic functions ... ." Blanchard defines "navigational cover" as "tolerably constant fixing accuracy over a good area irrespective of range (rather than the linear decrease of accuracy with range typical of point-sources)." (Blanchard 1991, 285).

There are a diversity of types of hyperbolic aids. One possible classification of these systems is offered by L.W. J. Fifield. He classifies them by baseline lengths (the distance between the stations in a hyperbolic unit):

- 1) "Very Short Base Line Systems". When the base line is very short (perhaps less than one mile) hyperbolae are virtually straight lines except in the immediate vicinity of the base line. Consol is a primary example
- 2) "Short Base-Line Systems". Base lines are approximately 50-100 miles in length. Example: Decca.
- 3) "Long Base Line-Hyperbolic Lines". Base lines can be 600 miles or more. Examples: Loran A, Loran C.
- 4) "Very Long-Range Hyperbolic Systems". Examples: Omega, Satellite Nav aids. (Fifield 1980, 165-176).

#### 4B2 Early Hyperbolic Aids

In 1938 Ernst Kramar of SEL reworked the US radio range system and created a new version called Elektra. Elektra was capable of emitting multiple equisignals that could establish multiple routes. Kramar then developed a second version that added direction data between the equisignals. This was termed Sonne (German for Sun). (Blanchard 1991, 311).

Sonne was a primary aid during World War II for Germany. A variety of aids precede and succeed Sonne; at least one alternate name (Consol) also grew out of Sonne.

Powell (Beck) refers to Sonne as a directional radio beacon (Beck 1971, 113). While Kramar (possibly the inventor of the beacon, and who wrote of it in Bauss) describes it as a rotating radio beacon (Elektra, the ancestor aid, he describes as a directional radio beacon). Sonne was the major German radio navigational aid in World War II. It was long-range and employed for submarine navigation among other purposes. (Kramar 1963, 29)

Consol is the more contemporary name for Sonne. Authors seemingly disagree as to whether Consol is simply another name for Sonne or whether some changes came about when the aid was listed under Consol. The workings of Sonne are seen through the Consol system. (IHB 1965, II.4-01; Kramar 1963, 29).

Consol is listed as a hyperbolic aid because its signals create lines that are hyperbolic in nature. But the lines are short causing it to be termed a "collapsed" hyperbolic system. It has been regarded as primarily a directional radio beacon operation. (Powell in Beck, 1971, 113). The Consol system did not have multiple stations. but instead its installations had a single station with three antennas at that station. The transmissions thereby created separate transmissions leading to establishing of lines of position. Consol was included in ICAO and some stations existed at least into the 1990s. A version known as Consolan employed two antennas instead of three. (Kramar 1963, 29, 33).

#### 4B3 GEE & LORAN Systems

Fully hyperbolic systems began with GEE and continued with LORAN which is, in some sense, a descendent of GEE. They are considered together because of that shared commonality.

##### a) Gee

An early -- if not earliest -- fully hyperbolic system was that of GEE; it can also be described as the first area-coverage aid (Blanchard 1997, 163). Its early stages can be

traced to the mid-1930s in UK. Early electronic studies focussed on developing radar including work on producing pulse transmitters, and the means of displaying data in aircraft via cathode-ray tubes. In that time most such tubes (Oscilloscopes or Oscillographs) were employed for lab work and were limited in production. R.J. Dippy proposed a navigation system in 1937 centered on pulse transmitters and cathode-ray tubes. Though this idea did not generate interest until 1940 during a time of growing navigation problems. (Blanchard 1991, 297-298).

Development and first trials of GEE took place in 1940. (Blanchard 1991, 298; Casabona 1959, 26-55 ). GEE became operational for navigation on bombing raids into Germany into 1942. GEE became the most important radio navaid in World War II. (Hall 1947, 60). There were GEE installations in UK and surrounding areas during the war, and beyond UK after the war. (Blanchard 1991, 298). A planned expansion of GEE after the war did not materialize. (Williams 1992, 230-231). However, Gee was still in operation in Europe into the late 1950s (Casabona 1959, 26-55).

GEE and Loran display similarities in their makeup and operations. Both are pulse-measured with Gee at VHF of 20-85 MHz (Loran-A was MF). (Bowditch 1966, 343; Powell in Beck 1971, 63). A GEE installation (known as a chain) consisted of a Master station and 2-3 Slave stations (Hall 1947, 60 ). (The terms of Master and Slave are common to Hyperbolic systems though they may appear curious in that context). Gee base lines were 75-80 miles in length. (Bowditch 1966, 343).

The master station emitted a pulse received by the slave stations. After an appropriate pause the slave station transmitted pulses. The several transmissions formed lines of position in lattice or matrix configuration. Airborne receivers electronically computed the differences in time as the pulses are received from A pulses (also termed master) and B, C, D pulses (or slave stations transmissions). The airborne receiver measured the incoming pulse times and then transferred the data to an indicator unit for delivery to

the crew. (Grover 1947, 57-58).

#### b) Loran

Beginning in the late 1930s (with some early 20th century antecedents) a group of hyperbolic aids grew up under the acronym Loran (which stands for LOnG Range Navigation). These are all "radio position fixing systems." The core principle is based on measurement of time differences of pulse signals from several transmitting stations. The LOPs (Lines of Position) are hyperbolae and signals are long range in nature. Loran-A and Loran-C are major operational systems within Loran. (USCG through IHB 1965). Other forms were developmental or short-lived systems. All hyperbolic systems are obsolescent -- if not obsolete -- because of GPS. (Williams 1992, 234). GPS is also hyperbolic but it is three-dimensional in nature, and space-based.

Loran-A is the original form of Loran. It has appeared under a variety of names: the single word Loran, HF Loran or Standard Loran. Its major area of usage was overland (while Gee was more of an aircraft navaid). Its frequency was 1700-2000 kHz and it produced one line of position at a time (Gee produced two) and base lines were 300 miles in length. Blanchard notes original frequency was 30 MHz but later 3 MHz which is higher than Hall's figures. (Blanchard 1991, 305; Hall 1947, 64).

Loran was the early US effort to create a hyperbolic radio navigation system of a pulsed nature. A major problem was achieving time-delay measurements that were accurate. This was also a problem for Gee but Loran-A used longer pulses at lower frequencies thereby adding to the problem. (Blanchard 1991, 305).

The original project was abandoned when the US became aware of Gee's existence. A new effort focussed on an over the water, long range system with a frequency of 1.95 MHz. A UK researcher, R.J. Dippy, heavily involved in Gee also became involved in Loran which thereby brought Gee ideas into Loran. A result was the

interchangeability of Gee and Loran at the receiver level. Loran-A became operational in mid-1942 (NY-Delaware based transmitters); system was operational in 1943. The system operated in pairs rather than in chains (as was the case with Gee). There were three basic frequencies: 1950, 1900, 1850 khz. (Blanchard 1991, 306).

Blanchard was of the view that Loran-A required a navigator (as found in military aircraft) and was not a pilot-friendly-aid. He notes that when the navigator was no longer present then Loran-A was doomed. Yet some use of Loran-A continued for quite sometime after the war. Seemingly non-military crews lacked a navigator. It ended operations in the Atlantic in 1980, but continued in the Pacific into the 1990s.

Navigation needs in the Pacific during World War II required a longer-distance navaid (during daylight hours) then was available. There were early experiments with low frequency Loran. Why LF? superior propagation of ground waves was available at LF. But the work was not successful since pulse measurements were not sufficiently accurate (LF needed long pulses). The required navaid required phase comparisons but the needed experiments were not carried out at the time. Because of development problems work was suspended in the early post-war period. In 1946 Sperry Gyroscope initiated a proposal for a system called Cyclan. Measurement was by phase-comparison and used two frequencies (100 kHz and 200 kHz). Ambiguities could be resolved by observing the differences between frequencies. (Blanchard 1991, 309; Kramar 1963, 119).

US Air Force ran tests on Cyclan in 1948 (employing 160 kHz and 180 kHz frequencies). They eventually settled on one frequency and the aid was given a new name: Cytac. It was seen as a possible military tactical aid. But USAF stopped worked on Cytac in 1951. However, Kramar states that USAF and Sperry carried out a study of a LF system in 1952-1957. That study focussed on a frequency of 90-110 mHz; 600-1000 nm base-lines were possible. There were two distance-measuring methods: a) pulse time difference measurements (resulting in hyperbolae when time

differences were equal); b) phase difference measurements (of carrier frequency). (Kramar 1963, 119).

U.S. Navy developed an interest in the suspended project ran tests on the old Cytac transmitters. Test results indicated the range of Cytac was 2,250 miles for "daytime groundwave range." And night time range was 1,650 miles. With skywaves it was 3,000 miles. The "time-difference accuracy" was substantial. The US Navy then set up transmitters in many locations and renamed the system Loran-C. It began as a marine system but considerable aviation use was made of it. Blanchard speaks of US Navy role but little US Air Force role while Kramar speaks heavily of U.S. Air Force. (Blanchard 1991, 309-310; Kramar 1963, 119).

Experiments in long range navigation aids during and after World War II were not confined to Loran-A and Loran-C. A variety of other ideas were pursued by a number of individuals and organizations. Some of these ideas did not advance very far while some became operational.

A variety of sources refer to Low-Frequency and/or Loran-B. Loran-B was LF and other forms not specifically so labelled can be subsumed under the title of Loran-B. The idea for this form began in late World War II (by Signal Corps and MIT Radiation Lab). It employed the same frequency as Loran-A but it was more accurate since it utilized both envelope matching and cycle matching. Presumably this can be translated into pulse measurement and phase measurement. Casabona described it as consisting of four transmitters at corners of a large square covering nearly 1.8 million square miles at night and over 1.3 million in the day. Trials were carried out in 1945. It had possible use in harbors areas. It can be seen as a developmental step to Loran-C. (Casabona 1959, 26-34).

A few references are made to a Loran-D which was seemingly a USAF tactical system (bombing aid). It used portable transmitters and used 16 pulses in its transmissions (in contrast to eight otherwise). Blanchard 1991, 310).

A final form of Loran is Skywave-Synchronized Loran or SS Loran. It was developed in the US and employed in Europe during World War II. It was developed in 1943 and operational by late 1944. As the name suggests it employed skywaves which increased accuracy and distance at night. Pulses were "bounced" off the e-layer of the ionosphere. It could be employed at night. Some sources seem to suggest it was an alternate technique for existing Loran. However, other sources suggest the need for a special receiver, or modification of ground equipment. (Smith 1948, 51; Blanchard 1991, 307-08; Casabona 1959, 26-34).

#### 4B4 Decca Group of Navaids

Decca, including its early development, dates back some 65 years. In addition to what became Decca Navigator System there are a variety of related aids. Some, even many, of the "family" of Decca are not in use. Nonetheless, they constitute a major element in navaid history.

Decca is an US invention though substantially developed in UK and very much associated with UK. The originator, W.J. O'Brien, worked alone from 1936 to 1939. He was apparently not aware of other researchers whose work had some resemblance to his work. The original name, Aircraft Position Indicator, had a more restricted goal: determining ground speed of airplanes undergoing performance trials. He offered the idea to civil, military agencies in the US and to military agencies in UK but failed to find any interested parties. (Blanchard 1991, 300).

O'Brien and a friend, H.F. Schwartz (a US citizen in UK and employee of Decca Record Co.), tried out a prototype in California with Decca's support. The prototype included a "master" station (at 300 kHz), and one "slave" station (at 600 kHz). Comparison of transmitted signals was at 1200 kHz and the system seemed to be workable. The transmitting frequency was different from earlier ideas though it remained "harmonically-related". The phase

comparison technique was of a design that did not require modulation. This new system required only a narrow bandwidth and limited power. However, the problem of ambiguity not eliminated. (Blanchard 1991, 307).

The Admiralty took an interest in the project by 1941 and carried out trials in 1942. Tests succeeded and development went ahead. QM (earlier name for Decca) was tested in January 1944 (with the idea of possible use at Normandy) and it was found to be superior to Gee. Decca was then selected for "Overlord." Decca was originally an aviation aid but it became substantially a maritime aid after World War II. It worked as well with marine users as had Gee for aviation. Ambiguity continued to be a problem. Lane identification was seen as a possible solution in 1947 but that did not prove to be a full solution. However, "Multipulse" in mid-1950s removed most of the problem. (Blanchard 1991, 302, 307).

In the 1960s Decca tried to gain approval from ICAO for inclusion as an en-route aid (over VOR/DME) but that effort failed. By early 1990s it was primarily employed by helicopters, smaller business planes at small airports where other aids were not available. It has been estimated that 50,000 ships of all types employ Decca and about 750 helicopters, fixed-wing aircraft. It remains primarily in private ownership. (Blanchard 1991, 302-303).

Major derivatives of Decca include Delrac and Dectra. Delrac is an acronym formed from Decca Long Range Area Cover (Blanchard has Cover while Grover has Coverage). A proposal was made in 1946 for VLF system for all of North Atlantic. It would have consisted of two stations in western Ireland which would give "track guidance" over "great circle track" (London-New York). A third station was to be set up in Bermuda (ranging). But Delrac was never operational though work continued on the idea. In 1951 Decca promoted a possible system for wide area coverage not restricted to set tracks. (Grover 1957, 117-118; Blanchard 1991, 303).

Decaa, after purchasing the patents for the World

War II era aid known as POPI, proposed both Delrac and Decca as long range nav aids. Decca hoped for an approval from ICAO as an approved long range nav aid. It was proposed to offer world wide coverage with 28 transmitters (instead of very long range with a few transmitters). The system would be similar to Omega (which did not yet exist) in a variety of ways. The system was to follow the Decca pattern. Supposedly Omega designers took many features of Delrac causing a legal action (the second by Decca). Delrac was intended for ships and planes equally. (Blanchard 1991, 303-304).

Decca (Decca Track). It was employed for creating a navigation track. Decca employed the Decca frequency band of 70-130 kHz. It utilized the Decca transmitters that were already in use. Transmitters were in Scotland, Newfoundland. However, Decca required aerials to be twice the normal height and transmitters four times as powerful. Range was to be 750 miles from each end. Decca constituted a bearing system rather than a hyperbolic one. Transmitters were so aligned that a track formed over the great circle in the north Atlantic. (Blanchard 1991, 304-305). Decca was also known as Trunk-Route Decca. (USNOO 1969).

The Decca organization had hopes that aircraft would "plug into" standard overland Decca then use Decca over water and then Decca again on land on the far side. However, Decca was not set up for aircraft. (Blanchard 1991, 305).

#### 4B5 Other Radio Navaid Forms

Gee and Loran, and the Decca group are the largest segment of Hyperbolic Aids existing over a period of 60-some years. There are also other aids which are at least partly hyperbolic in nature. This treatment reviews the pertinent entities as discrete topics in a context of hyperbolic activity; a more chronological and interwoven treatment may have been advantageous. Radux & Omega are more extensively covered, other aids less so.

#### a) Radux, Radux-Omega & Omega

Omega and its antecedents can be traced back to World War II. The ubiquitous J.A. Pierce engaged in low frequency and very low frequency research during World War II. The results of LF Loran trials in 1945 indicated that frequency proved not be sufficiently accurate. An attempt (probably by the same Pierce in 1947) was made to add modifications to the tests but the tests were not very successful. However, it was thought it would work for LF (for example, at 10 kHz) and thereby resolve ambiguities. This phase is Radux. (Blanchard 1991, 310; Sakran IEEE 1998, 86).

A composite installation was tried that emitted a 40 kHz with modulation of 200 Hz with superimposed bursts of 10 kHz. The results were 40 kHz transmission that was accurate. The 10 kHz resolved the ambiguities in the 40 kHz, and 200 Hz resolved the ambiguities in the 10 kHz. This system was termed Radux-Omega. But it was not successful. It was found that 10kHz has greater range than the 40 kHz. And the short baseline of 40 kHz impinged on emissions of 10 kHz. (Blanchard 1991, 310).

The advent of inertial navigation systems and much greater electronic reliability (after the invention of the transistor) brought about a changed climate. One result was that ambiguities became less of a problem and a single frequency system might be possible. Therefore, the 40 kHz (Radux) dropped out and a new 12.5 kHz system was created. Tests results in the 1950s were successful. This became Omega. (Blanchard 1991, 310).

Experimental transmissions began in 1955 and it became operational in 1982 (1983 in Blanchard). (FRP 1990, 3-14). Pierce created and directed the Omega Implementation committee. (1963) (Blanchard 1991, 311). Omega was developed and instituted by the US Navy with US Coast Guard assistance (FRP 1990, 3-14). Omega was at much lower frequency than Loran with wider coverage. It required fewer transmitters with signal matching thereby following a different process. (Maloney 1985, 467).

Omega was a newer hyperbolic system than Loran and substantially superseded Loran-C for long-distance navigation. Yet Omega is gone while some Loran-C stations still operate. The advent of GPS dramatically and drastically altered nav aids and eliminated the need for Omega though users for Loran-C continue to exist. Omega ended its navigation, positioning, and timing role in September of 1997. (FRP 1999, 1-10).

#### b) Other Radionavigation Systems

These systems generate some degree of confusion. They are partially hyperbolic in nature. Navaglobe is a LF rotating radio beacon that began operation in 1947. It was a product of USAF and ITT Labs and demonstrated at an ICAO Conference in 1954. It was a long range aid transmitting on 100 kc/s. An early decision was made to add DME which would create a rho-theta system (known as Navarho). (de v. Hauteville 1963, 73).

A system known Facon provided the DME phase. Navaglobe added to Facon resulted in Navarho. The complete system was tested in 1956/57 (Camden NY). It supplied both distance and bearing data. But it fell short of ICAO requirements. Several forms of Navarho were developed. (de v. Hauteville 1993, 73).

"POPI" (Post Office Position Indicator) was a World War II system commissioned by the UK Post Office. It was of a hyperbolic nature employing a continuous wave (cw) phase comparison system. It is similar to Decca though using shorter base lines and displayed more lineal LOPS. Some features are similar to both Consol and Decca. It was later purchased by Decca Co. (Blanchard 1991, 303; Casabona 1959, 26-19-26-20).

A variety of systems had grown up in the 1950s and 1960s. Some were largely navigation aids while others were more hydrographic and, at most, only partial safety aids. These included Raydist, Lorac, Rana and Radio Mesh. The T-M Database provides some information on them.

## 4C Satellite Nav aids

### 4C1 Introduction & Early Satellite Aids

Satellite Navigation (1) may be a sufficient term for Nav aids employing satellites. Though in many instances the lack of "Aids" in a term including "Navigation" is not sufficient for a safety aids description. Possibly the close relationship of satellite and navigation to a system of aids sufficiently suggests its aids character. At the least, Satellite Navigation is often so employed in the literature. Permutations of the basic term include Satellite-assisted navigation (2), Satellite-aided navigation, Satellite-based navigation (3), and Satellite-Based Radio-Navigation System (4). (1. Underdown 1993, 221; 2. Wright 1971, 327; 3. Bethmann 1984, 332; 4. Johns IJ 1997, 7).

Developments in rocket research and microwave engineering inspired Arthur C. Clarke to promote the idea of radio systems aboard orbiting satellites already in 1945. By 1954 studies on the idea of communication satellites were well underway. In 1957 the Soviet Union launched the first satellite in earth orbit, Sputnik I. (McGraw-Hill EST 1992, Vol 4, Cli-Cyt, 193).

In the late 1950s US Navy required a global system for position-fixing because of the arrival of the Polaris SSBN submarine into the fleet and its world-wide navigation needs. Loran-C coverage was extended and that partially met the Navy's need. The Omega navigation system was still a concept at this time. The launching of Sputnik I accompanied by many other changes in electronics and technology opened the way to a global navigation system. (Hobbs 1990, 572).

The satellite navigation system concept developed before the end of 1957. Johns Hopkins scientists determined Sputnik's orbit from calculation of its Doppler shift. This suggested that such a measurement could be applied to determining the position of a receiver in relation to the satellite. (Williams 1992, 238). In 1958 Applied Physics Labs awarded a contract to develop a satellite

system. In 1960 a prototype was launched at Point Mugu, California. (Hobbs 1990, 572). In 1964 the US Navy Satellite System (NAVSAT) was officially operational. This followed the launch of the first Transit satellite into orbit. Transit became available for private, commercial use. Within the Navy the original acronym of Navsat was employed while outside the Navy Transit Navigation Satellite System; Transit was a commonly employed name. (Hobbs 1990, 572-573). However, Danchik in Kayton refers to it as Navy Navigation Satellite System. Later, the European Space Agency developed a system also known as Navsat. (Kayton (Danchik) 1990, 157). The Transit system grew to a fleet of seven satellites (FRP speaks of eight plus spares). (FRP 1990, A-36; Kayton 1990, 157)

Transit was the first navigation satellite system in operation. The second was Cicada from the USSR which was similar to Transit. (Parkinson 1995 *NJIN*, 109-110). In time Transit was superseded by GPS. Transit was scheduled for shutdown in 1996 because of its obsolescence. (FRP 1990, 3-28). However, Transit existed for nearly 40 years from conception and nearly 33 years in operation (Parkinson 1995 *NJIN*, 110).

Transit was not the only satellite system under development by the US Navy. During the late 1950's/early 1960s a second US positioning, navigation systems Timation was under study. Timation, was a concept, possibly in a prototype mode, but never launched. (French 1996, 15). The US Air Force was also involved in satellite studies. Their proposed system, System 621b, apparently did not become operational. By the early 1970s the US military force had a critical need for a satellite navigation system of high precision. In 1973 the Department of Defense called for the merger of Timation and System 621b. The merged system was to be called the Defense Navigation Satellite System (DNSS). French remarks that "from this emerged a combination system concept" termed Navstar. The new system was to be three-dimensional system and of continuous operation providing latitude, longitude and altitude data. Transit, by contrast was periodic in operation and two-dimensional. (French

1996, 15). Timation and 621B are predecessors of GPS and vital elements in its development. (Parkinson *NJIN* 1995, 110).

## 4C2 Global Positioning System (GPS)

### a) Origins & Development

The older separate efforts of the Navy and Air Force became the GPS Joint Program. The participants included US military agencies, Defense Mapping Agency (DMA), Department of Transportation (DOT) and also NATO. It was based in Los Angeles under the administration of the Air Force's Space Division. GPS was intended to provide three-fold position (3-dimension), velocity, and "precise-time information." (Runkle IEEE 1988, 1).

Governments are adept at coining acronyms and NAVSTAR follows that tradition: Navigation System with Timing And Ranging. During the first phase (1973-1979), in French's wording, was a time of "Concept Validation". In 1977 the initial launch was carried out (NTS-2 = (Navigation Technical Satellite 2). And in 1978 the initial "Block I Navstar GPS SV" (SV= Satellite Vehicle) was launched. (French 1996, 15).

During the second phase (1979-1985) a major development and testing took place. The third phase began in 1985. In 1989 the initial "Block II Navstar GPS SV was launched. In 1993 the DOD announced "Initial Operational Capability (IOC)" with minimum of Block I and II satellites. And in 1995 the "Full Operational Capability" (FOC) was achieved with a full complement of 24 Block II satellites. (French 1996, 17).

GPS satellites transmit signals on two frequencies (1575.42 MHz and 1227.6 MHz). The frequencies carry information codes and a navigation data message. The information is the position of the satellite in reference to time, distance between satellite and receiver. (Hobbs 1990, 584-585).

Satellite navigation has grown at a very fast rate. GPS which began as a military system is employed mostly by civil users. And professional users are far fewer than amateur users. It is thought that those users, mariners and pilots, will, in turn, become far fewer than land-based users. Last terms GPS as a "consumer utility for the whole world, free of cost and freely available!" (Last 1997, *NJIN*, 226-227). Yet GPS cannot maintain maximum accuracy throughout the world continuously. Satellite failure or terrain can dilute accuracy. It remains a military system and its standards reflect that situation. Its standards are "not those of civil safety-of-life aids to navigation." (Last 1997, *NJIN*, 226-227).

#### b) Augmentation

To speak simplistically, the last 250 years have seen more and more safety aids and even new transportation modes. Safety aids both in types and in numbers have grown enormously. To take one example, fog signals consisted of bells and cannons in the 18th century but they expanded to include a wide range of horns, whistles, sirens, explosives, devices powered by air, steam, gas, electricity, gunpowder. Yet now there is a shrinkage. For example, fog signals are substantially gone and traditional lighthouses are on the wane. And many aids that remain are less significant in the face of electronic aids. Yet it is extremely unlikely that there can ever be a single form of Transportation-Marking. No one system, no one safety aid can cover every kind of situation. The gamut of T-M forms can not be reduced to just one. Some portion of the spectrum of aids needs to continue in some manner or other. A Universal T-M in a unifocal mode can be little more than a pipe dream.

Yet one form of T-M may come closer to that mythical state than any other. That form is GPS though not GPS in its essence. The core of GPS requires a variety of devices, systems to turn GPS into a very encompassing and precise mode of operation. Many of these devices and systems go under the name of Augmentation: they augment GPS by providing needed corrections thereby reducing

error and simultaneously creating a high level of precision. Much of this development came late in the 20th century and its realization will substantially occur in the 21st century. It is included in the study as a concluding element to the 250 years of this study, and as a threshold to another era.

Differential GPS is an overarching term that encompasses the means for correcting, improving GPS messages. Often, especially in aviation, other more specific terms are employed more often than DGPS. DGPS improves GPS by adding differential corrections to measurements from the satellite and its transmissions. DGPS has more local knowledge and can correct GPS signals. The corrections are sent to receivers which can alter the basic message. (National Civilian 2000, 5). Ward notes that this role has been carried out for nearly ten years though he employs the broader term of differential GNSS (Ward 1998, *NJIN*, 153-155).

Traditional radiobeacons take on a new lease on life as they take up a role of providing differential corrections. IALA has prepared world-wide standards for DGPS radiobeacons. Finland and Sweden began a joint system in the mid-1990s. Iceland has also established a full system of such aids. (Thorsteinsson 1995 *NJIN*, 558). US Maritime DGPS began operation in 1999. Reference stations that transmit "pseudorange corrections" (on-board receivers are less accurate than satellites and receivers develop pseudo or false range measurements which need to be corrected. (Logsdon 1992, 13). USCG is disbanding any radiobeacons that are not employed for this new purpose. (FRP 1999, 1-9). Two English writers refer to this form of DGPS as radiobeacon DGPS. (Last & Ward 1995, 36ff).

"Nationwide DGPS" according to US FRP is an expansion of the maritime service. It is intended to blanket surface areas of the U.S. A variety of agencies including the Federal Railroad Administration, Federal Highway Administration and NOAA are involved in this effort. (FRP 1999, 1-9). Experimentation is underway for railway usage of GPS both for collision avoidance and train location

techniques (Carley 1998 *WSJ*, A-1). This blanket coverage is needed with the spread of GPS. Already small personal receivers have become available for increased usage of GPS. (USC Family Magazine Spr 1998, 63; Gleick *NYT Magazine*, 4-4-96, 19). One approach to land DGPS employs VHF FM radio in which corrections are superimposed on broadcasts (Last 1997 *JN*, 226).

Wide Area DGPS (WADGPS) offers coverage for continents and ocean navigation. WAAS, LAAS, EGNOS are further elements in a kind of GPS alphabet soup. WAAS or Wide Area Augmentation System provides satellite-based corrections for en-route, terminal, landing assistance. Europeans have contributed EGNOS or European Geostationary Navigation Overlay System for this purpose. (Last 1997, *NJIN*, 226). LAAS or Local Area Augmentation System is a ground-based version that complements WAAS; in a sense augmentation of augmentation. (Braff 1998, *NJIN*, 411). Acronyms such as SBAS and GBAS are, in a sense, variant forms of previous terms: SBAS=Satellite-Based Augmentation System, and GBAS=Ground-Based Augmentation System. (FRP 1999, 1-10).

#### 4C3 Other Satellite Systems

At present a measure of confusion is generated by the term Global Navigation Satellite System (GNSS). It suggests a system of world-wide dimensions that is other than GPS. It is in actuality other than GPS yet it is also GPS. GNSS refers to a global system acceptable to all users. For ICAO GPS and the Soviet Glonass constitute GNSS in its current form. However, some groups, such as the European Tripartite envision a second GNSS (or GNSS 2) that will be international in scope and not tied to one nation such as is the case with GPS. (Steciw, Storey, Tytgat *II*, 11-97, 13-15, 26).

In a response to the Norwegian government the U.S. State Department has indicated the worthiness of a goal of a GNSS that would have international ownership and the desire for moving in that direction. ICAO, IMO, EC are all

involved. Andrade notes that GPS and Glonass have "been offered to the international community as a means to support the evolutionary development of the GNSS." (Andrade 2001, 24). Though an observer may view GPS in itself as a global feature and fixture. The term takes on future dimensions yet is interwoven with current usages.

In summary, there may be several phases: the present one with augmentation, a GNSS I phase with GPS, Glonass "enhanced by geostationary satellite overlays" and eventually a GNSS 2. (Last 1997 *NJIN*, 230-231). Though one may wonder that since GPS exists and works and represents the status quo, if inertia will lead to keeping GPS no matter its flaws.

The former Soviet Union created many systems that were independent of yet comparable to US efforts. These counterparts of US include extensive satellite navigation systems. Tsikada, an older Soviet system, began in the mid-1960 and was the equivalent of Transit. With the advent of Glonass, Tsikada was to be phased out. (Forsell 1991, 329).

The Glonass system began in the 1970s and the first satellite launched was in 1982 and other satellites launched thereafter. It was intended to be fully operational by the mid-1990s. Many of the satellites launched have had short life-spans. US and former USSR reached an agreement for "common use" of the systems. Efforts for receivers that can received both systems are in process. Signals are somewhat similar to GPS. (Forsell 1991, 329).

There have been other navigation satellite systems and systems of a private nature. These systems were created at least in part because in the earlier phase of GPS military needs were primary and accuracy was greater for military uses. Starfix was developed in the early 1980s and became operational in 1986. It served the needs of petroleum and seismic companies. (Ott IEEE 1986, 8). Other systems include Geostar/Locstar. They began in the 1980s as well. Geostar is operated by a company of the same name. Locstar, located in Europe. was developed by

CNES, a consortium. Both were centered on coverage mid-latitudes of N. America, Europe, Middle East, Africa. The systems are "two-way ranging system with two-way information transfer capability." Starfix is a commercial operation serving primarily petroleum interests and also surveying companies. It employs pseudo-range methods. (Forssell 1991, 330).

#### 4D Final Approach & Landing Aids

##### 4D1 Introduction and Early Years

The title for this sub-chapter is a variant of an ICAO AT term. While the version in ICAO may be employed elsewhere it is substantially associated with ICAO and only infrequently employed otherwise. It includes only radio navaids (ILS, MLS) though it can also suggest visual aids. FAA (US) employs the term Terminal Navigational Aids which is somewhat akin to Final Approach & Landing Aids though the US term clearly includes visual forms. The related terms landing aids and landing aids to air navigation are general terms though occasionally a radio navaid-only meaning can be invoked. (ICAO AT 1996, 2; Grover 1957, 95); Database Iiv).

Many developments in final approach and landing aids are rooted in the 1930s and 1940s though there are earlier developments including some events in the first years of practical radio. Kendal 1990 notes that by 1912 essential principles of several major navigation systems had been established. One of these, the Scheller Course Setter of 1907 was the predecessor of Lorenz and SBA; and a somewhat remote ancestor for current-day ILS. Wilson 1979 notes that the US government began work on what would become ILS in 1919 though few details are provided. A second source, Brady 1993 also refers to early experiments that began in 1919 though other references apparently do not refer to that early event. (Kendal 1990, 317; Wilson 1979, 127; Brady 1993, 109).

Wilson notes that in 1929 the US Bureau of

Standards tested the first ILS system. Charnley refers to a "Radio Beam System" in the late 1920s in the US. Charnley also notes that Jimmy Doolittle assembled his own "radio homing aid" as well as aircraft navigation equipment for experiments in 1929. (Wilson 1979, 127; Charnley 1989, 163).

"Early Beam Approach Systems" include the Lorenz System and a version known as Standard Beam Approach or SBA; the former is German in origins while the later is British. Lorenz was a version of the Course Setter from early in the century. It provided azimuth guidance and also include marker beacons which provided remaining distance information. (Kendal 1990, 321, Grover 1957, 96-97). Keen uses variant names, descriptions for some earlier aids. The US efforts that lead to ILS has the name of the Blind Landing System. While Lorenz becomes Lorenz Thick Weather Landing System. Keen describes some earlier efforts that seemingly received little attention in newer treatments of historical topics. (Keen 1938, 623, 643ff, 630).

Standard Beam Approach (SBA), produced by the Standard Co, included azimuth guidance as well as marker beacons. SBA transmissions were similar to those of a radio range. SBA's range was 25 miles. Its signals were in the form of dots and dashes: a dot signal denoted plane to left of beam while a dash denoted right of beam. There was no glide path element as such but a "signal-strength meter" provided some glide slope data. Grover notes that though both systems are early they retain importance because they are the foundation for current continuous-wave navaids. Kendal is seemingly positive to SBA noting its use over many years. However, Williams notes it was not very successful during World War II and this view is echoed by Smith 1948. SBA manifested several problems including the lack of an actual glide slope (or path) unit. SBA began service in 1939. (Grover 1957, 96-97; Williams 1992, 191).

Charnley refers to work by the German firm Siemens, for a radio beam system in the late 1930s. This system provided guidance for azimuth and distance measurement.

Siemens was of the view that the quest for a blind landing method had its solution in this system following testing. But the plane used for testing was of limited power and the airfield was of grass and the test results fell short of any full solution. Seemingly only Charnley refers to Siemen's work. (Charnley 1989, 164). Smith 1948 also refers to two systems that receive little attention. Both are during World War II. One system is termed the V.H.F./B.A.. It was a wartime system for fighter aircraft though not entirely successful. Standard Telephones and Cables created a glide path unit. It was also worked on during World War II but was not entirely successful. (Smith 1948, 91-92).

#### 4D2 ILS (Instrument Landing System)

The Instrument Landing System (often known by acronym of ILS) is regarded as a direct descendent of the Lorenz approach system. It was known as SCS-51 during its development in World War II. A unit termed a localizer creates azimuth by creating continuous wave patterns that overlap. Glide path information consists of a second set of transmitted patterns. The system provided both directional information but also rate of descent data. Marker beacons accompanied the primary units and provided distance to go information. (Grover 1957, 98).

During the early 1930s the US selected VHF as the frequency for ILS and the three components of the system: Localizer, glide path and marker beacons. By 1933 an elementary system had been achieved. But the Bureau of Air Commerce in examining various ideas decided they wanted something more sophisticated than that early version. The RTCA (Radio Technical Commission for Aeronautics) by 1937 presented to the BAC (Bureau of Air Commerce) principles for ILS, and also established specifications. Bids were called for and International Telephone Development Company (ITD) won the competition. However, other firms continued to work on their systems. But RTCA favored ITD. (Wilson 1979, 125, 128). Underdown 1993 notes that ILS was originally intended to be a "blind landing system" but that goal was not reached and instead it was an "approach to landing" aid.

(Underdown 1993, 93, 112). The desire for a system to be used in complete darkness runs through the early years of work by various individuals and groups for an airport landing scheme. Charnley speaks of Signal Corps system in late 1930s. Early work led to SCS-51, forerunner of ILS; an early demonstration was carried out in UK in 1944. (Wilson 1979, 128; Underdown 1993, 112; Charnley 1989, 164; Brady 1993, 109).

The National Academy of Sciences (NAS) studied ILS (with participation of Army, Navy, CAA). NAS favored ITD though this was accompanied by the hope that microwave could be used in the future. ITD received go-ahead in May of 1940. The CAA wanted to move ahead "with all possible dispatch." But a speedy completion proved to be impossible. The beginning of World War II conspired against any rush. The Army developed an interest in microwaves; the Navy became interested in a different system. Kayton speaks of ILS as being introduced in 1941. While that is true in some sense, it did not get any further for quite sometime. The CAA continued to work on ILS and very much wanted to inaugurate it in 1945. However, the US military was working on a new way of instrument landing during World War II: The new system employed radar. (Wilson 1979, 128-129; Kayton, 237; Smith 1948, 93).

The new system was called GCA: Ground-controlled Approach. It consisted of a large radar scope for locating planes near airport, and smaller scopes for azimuth, and for elevation information. Humans working radar screens would give directions to pilot using radar data. There would be no airborne equipment. (Wilson 1979, 128-129).

Airborne crews, by contrast would have a major role in ILS. CAA's ILS consisted of three components on the ground: localizer, glide path, marker beacons all on VHF. Airborne reception equipment consisted of receivers for localizers, glide path, marker beacons. Still other instruments recorded passage over marker beacons through red and green flashing lights. (W. Kroger AW, 3-47, 31 in Wilson 1979).

There were hints of possible conflict between GCA and ILS backers already in 1945 when indications surfaced that AAF might favor GCA over ILS (even though Army Signal Corps was responsible for the SCS-51 version of ILS). Private pilots, military pilots favored GCA but professional pilots wanted control over their planes; hence ILS. Solberg sums up the conflict as one of ground control vs cockpit control. By 1946 CAA admitted to seeing value in GCA as a supplement to ASR (Airport Surveillance Radar). Nonetheless, CAA wanted ILS for landings. Tests at Indianapolis decided that neither approach constituted a blind landing system but instead both were "low-approach systems." (Wilson 1979, Solberg 1979, 332).

In December of 1946 PICA0 selected ILS as "primary landing aid for all international trunk airports" (ICAO adopted ILS in 1948). (Charnley 1989, 166). PICA0 had already examined GCA as well as some European alternatives. PICA0 viewed radar as a supplement. By 1947 CAA accepted PAR, precision approach radar, and ASR, airport surveillance radar, as backups. Braniff began using ILS and the value of the system began to be seen. RTCA (Radio Technical Committee for Aeronautics) was given the assignment to produce "Common civilian-military program of nav aids." SC-31 (Special Committee) approved VOR, DME. ILS was okayed for most air carriers, some military craft but PAR to be part of ILS, and ASR was recommended. Solberg notes that ILS installation of a rudimentary form were employed at some airports in 1947. By early 1950s in US there were over 140 ILS installations and 10 each of PAR and ASR. (Wilson 1979, 217-218; Solberg 1979, 331).

#### 4D3 MLS

The intended replaced for ILS, Microwave Landing System (MLS) is in an anomalous state. It was to be the "wave of the future". It was thought to be superior to ILS since ILS had displayed a variety of limitations. After much study and expense MLS was beginning to take shape, to have practical impact on aviation. But the rapid growth of

GPS and its precision augmentation of DGPS (as well as other systems) brought the value of a very incomplete MLS into question. Perhaps MLS is not yet dead though its future is very questionable. Two questions need to be asked about MLS: why was MLS seen as necessary in the first place? And was MLS different from ILS and perhaps superior to ILS?

Despite studies of ILS and the making of various improvements problems remained with ILS. VHF, on which ILS was based, was an increasingly limited resource because of VHF radio stations which were increasing in numbers. At times site problems and installation deteriorated the quality of signals, beams of ILS. Some observers therefore concluded (even in the 1940s) that a new system employing microwave frequencies was needed. (Charnley 1989, 166).

By the late 1980s ILS was already 40 years old. By 1970, ten years previous, some 50 successor ideas had surfaced that challenged ILS. RCTA's Special Committee 117 (SC117) began work on new system in 1967. Results were presented to FAA in 1970. AWOP (All Weather Ops Panel) of ICAO carried out similar work in 1978. By mid-1970s there were two primary contenders for a replacement system: a microwave system employing Doppler technology DMLS, and one employing Time-Reference Scanning Beam (TRSB). ICAO decided to replace ILS with TRSB in 1978. Australia and U.S. had promoted TRSB while UK promoted DMLS. The U.S. approved TRSB in 1975. There was considerable and vociferous debate leading to the decision. A spectator to these events may wonder if politics and political clout were at work here as with some older aids approved by ICAO. (Charnley 1989, 182; HR 1984, 9; Forssell 1991, 182-183).

MLS has a higher quality signal than that of ILS. Siting problems (due to nearby hills and other factors) are less a hinderance to MLS than ILS. ILS focusses on a single and narrow approach path while MLS can deal with a much wider path. (Charnley 1989, 183; HR 1984, 12).

US halted work on MLS in 1994. Despite weighty pronouncements about the shortcomings of ILS there is another view represented in the literature. Some have noted that ILS was improving and that, in fact, Category I operations were meeting most of aviation's need. In fact ILS could cover most of the bases. However, it could not cover all situations and the problem of FM interference was growing. And while US aviation is mostly Category I the situation in Europe is different: Category III is relatively common. Perhaps an aging system manifesting a variety of limitations was becoming vulnerable even if it could deal with most situations. Perhaps a single system was needed that could address limitations and be open to future needs and changes. However, MLS is apparently not that system. Serious work did not begin on MLS until a decade after Sputnik and satellite advances in navigation have quite outstripped the development of MLS. GPS is the probable wave of the future. (Forssell 1991, 182-183; Pilling 1994, 31).

## CHAPTER FIVE

### SOUND SIGNALS

#### 5A Marine Fog Signals

##### 5A1 Fog Signals, 1750-1870

Fog Signals, before 1750, were limited in variety and numbers. Early signals were either cannons or bells (and possibly gongs). More diverse and sophisticated forms required developments in technology (the availability of metals and the means of shaping and forming metals) and growth in transportation. The 19th century would see the development of mechanically-operated bells, sirens, reed horns, and whistles. Other forms developed after 1870.

An early fog signal, the bell, took on new importance during the first Industrial Revolution because of greater trade, maritime activities. Early fogbells included Poolberg, Ireland (1811) and Bell Rock, Scotland (1812). (Edwards 1884, 155). The first fogbells were employed in the US beginning in 1820 at West Quoddy, Maine. In about 1838 a tidal-powered bell was begun at Whitehead Lighthouse (Floherty 1942, 37). Tidal action affected a floating boom that caused weights to be wound up though sea action often tore apart the boom (Wheeler S-1990, 22). That bell was the precursor of clock-work mechanisms for bells. Such mechanisms activated a sledge hammer that struck the bell. The frequency of strikes was regulated by how often the mechanism was wound up (Wheeler S-1990, 22). Stevenson describes a mechanism at Bell Rock before 1820 that operated both the reflector's revolving mechanisms for the light and also operated a fog bell (Stevenson 1959, 81). Clock-work strikers were eventually replaced in the 20th century by strikers activated by reciprocating pistons. (USCG1953, 25-5-6).

Bells were not very successful at coastal locations because they could be heard only for short distances. They were frequently employed in harbors and rivers where a short range aid was adequate. One observer in 19th century

England noted that at one location a cannon could be heard for eight miles but the accompanying bell was never heard at all. (Extracts 1861, 69).

Writers on fog signals often speak of fog signal developments in specific, concrete terms. Yet a variety of authors describing sirens seemingly take a different approach with that fog signal. That coverage tends to be shorter, less detailed, passes over origins and reaches a developed state quickly. Talbot notes that the siren's invention was obscure and it "was brought before the U.S. government in a primitive form." Obscure origins may then explain why the siren has a less precise account of origins. (Talbot 1913, 60).

One author, Johnson, by contrast gives a detailed account of the siren in 1890. Johnson relates that A. and F. Brown (NYC Progress Works) adapted an instrument invented by Cagniard de la Tour (Johnson 1890, 17). What was the purpose of the Tour instrument? That is not explained. A Professor Henry (scientific advisor to the USLHE) provided guidance for the Browns. The siren was developed at the behest of the U.S. Lighthouse Establishment. (Johnson 1890, 17). Wheeler notes that the siren was tested in 1867 and became installed at Sandy Hook East Beacon in the following year. (Wheeler F-1990, 11; Conway 1915, 41). Possibly this siren was somewhat at variance with the English form that was undergoing development at about the same time.

The siren became a more effective and efficient aid after the work of several British researchers. A Professor Holmes prepared a version consisting of a revolving disc with slots attached to a similiar disc that was fixed. (Talbot 1913, 59-61). Talbot notes, "If the revolving disc completes 3,000 revolutions per minute and there are twelve slits in the disc then a total of 36,000 vibrations per minute is produced." The end result was a very loud, piercing and long distance sound (a 20-30 miles range was not unknown). Holme's version was first displayed at the Paris Exhibition in 1867. Talbot refers to a Mr. Slight as the modern siren's inventor. He does not specify how Slight

improved the siren except to note his slight alteration improved the siren by reducing strains on the mechanism that might have otherwise caused a breakdown. (Talbot 1913, 59-61).

Sutton-Jones in his work, *Pharos* (Sutton-Jones 1985, 110), mentions the the Browns in regard to the siren though not Holmes (he is, however, mentioned in regard to the Reed signal). In 1874 the Browns shipped a siren fog signal to England which underwent experiments at South Foreland. Mr Slight's improvement consisted of using a cylinder instead for of a disc for the signal. Older forms employed discs while the newer form employed a rotating cylinder with slots placed within a casing. (Wheeler 1990, 11). The end result of both forms was similar. Seemingly Slight's improvement resembles that second form. James Douglas also played a role in development of the siren signal. (Findley/Kettle 1896, 15). Compressed air produced by caloric engines was generally employed in UK. Lack of water at many stations precluded use of steam. (Edwards 1884, 175-176).

Talbot and other authors have noted that the reed horn (a similar version often known simply as the Trumpet) was the foundation of the siren. (Talbot 1913, 59). The earlier aid employed a large trumpet, with steam or compressed air that blew through a metal reed thereby creating a distinctive sound. The basic notion could be altered for a variant sound such as that of a siren. Trumpet could be employed as specific name when no other aids using trumpets were in use. (Talbot 1913, 59). DeWire likens the the trumpet in appearnace to a giant megaphone. DeWire 1995, 76).

The reed horn is known by several terms which can generate confusion. This signal, or an early form was often termed simply trumpet or Daboll's Trumpet. (DeWire 1995, 74; Conway 1915, 40). At the time no other signal employed a trumpet and therefore a distinguishing mark of the signal became its name and nearly a generic name at that. Conway notes that the reed horn is "a somewhat similar device" to the trumpet. (Conway 1915, 40).

Possibly the early form was primitive and the developed version was somewhat at variance in its design and construction though both employed a reed. Edwards seemingly sees horn, trumpet and reed horn as one aid. The carrying distance of the reed horn was somewhat limited and in time it was only employed where shorter distance aids proved to be adequate for navigation. (Edwards 1884, 170).

A final fog signal of this era is the whistle. Robert Foulis experimented with a whistle (the first fog signal to be powered by steam) in about 1850 in Canada. Daboll experimented with a whistle powered by a horse powered installation in 1852. (DeWire 1987, 160-161). Tests of earlier whistles were not altogether successful possibly because the early whistles were too small. Experiments at Beavertail, R.I. in 1855 employed a 5" whistle which was only half as large as later whistles. (Wheeler F-1990, 10). Later use of locomotive type whistles proved to be much more successful.

In 1859 a Colonel Bache experimented with a locomotive whistle mounted over a natural blow hole at the Farallones. While the initial attempt was not long lasting the whistle was effective in creating considerable noise. The first regular usage of a more conventional whistle was at West Quoddy Head and Cape Elizabeth in 1869. (Conway 1915, 41).

Whistles became a major fog signal form in North America but they never caught on in Europe. European reluctance may have stemmed in large part because of a fear of confusing fog whistles and ship whistles. (Wheeler F-1990, 10). The whistle was also more expensive to operate. Some UK sources considered the whistle as generating less sound. Perhaps that may have had to do with the size of the whistle. (Extracts 1861, 155). Yet Edwards notes even very powerful whistles were less adequate than other generating systems (Edwards 1884, 169).

Wheeler notes that by 1870 the aforementioned four new forms (mechanical bells, reed horns, whistles, sirens)

"were perfected and all standard fog signals" (Wheeler F-1990, 11). 1870 corresponds with the end of the first Industrial Revolution if one can measure such events that precisely.

Early floating sound aids included a bell buoy and a bell float. The original sound buoy was probably Brown's Bell Buoy in 1852. (Wheeler 1990, 11). A Lt Brown (US Army, on loan to USLHE) designed a buoy that, according to Wheeler, displayed a design markedly akin to current forms. But bell activation was a different matter. Brown devised a grooved metal plate beneath the bell. On the plate was a cannon ball. The motion of the sea caused the cannon ball to move and thereby strike the bell ringing it. Later on tapers (outside the bell) hung from the buoy's superstructure rang the bell even in nearly calm seas. (Wheeler F-1990, 11).

A second sound aid was the bell boat. It was authorized in 1841 yet the first boat was not employed until 1852. (Wheeler F-1990, 11). The boat was of wood construction but reinforced with iron. It was anchored to harbor bottoms but frequently broke loose or capsized. It was to be a short-lived aid. It was apparently older than the bell buoy though the dates are in close proximity. It is possible that Brown's Bell Buoy took some time to become relatively commonplace. (Wheeler F-1990, 11).

## 5A2 1870-1920

Sutton-Jones speaks of the "Age of Magnificence" in his tome, *Pharos: The Lighthouse Yesterday, Today & Tomorrow*. While his review of that age covers many years the perfected lighthouse seemingly occurred in the years 1890-1912. (Sutton-Jones 1985, 107-114). Sutton-Jones includes a subset of that age termed "The Gargantuan Sound" which perhaps occupies an equivalent span of years. In his sound remarks he refers to the fog signal at Little Cumbræ Lighthouse, Scotland. The diaphone signal at that station was of a special design with elongated piston and cylinder. Sutton-Jones notes that the signal "produced a sound of about 100 hz and was truly formidable and almost

seismic--the gargantuan sound." (Sutton-Jones 1985, 105). That may well sum up the zenith of fog signals. Though even in that zenith the beginnings of radio aids were already underway and the foundations of sound signals -- as well as visual -- were already becoming undermined.

The later 19th and earlier 20th century is a tumultuous time for fog signals. A great diversity of signals were created emitting a cacaphony of sounds that thrust into the fog from harbor entrances, rock towers and headlands; where ever ships traversed sea-lanes and harbors. Some signals were steam-powered, others air-generated, an occasional signal electric-powered.

Explosive signals in the form of cannon were already a well-established fog signal form. Yet even in the later 19th century experiments leading to new forms of explosive signals were developed. Experiments determined that a "24-pounder howitzer short gun" to be of superior quality as a fog signal though where and to what extent such an aid was used in the 1870s is unclear (Sutton-Jones 1985, 108). Experiments in Ireland with gas guns and rockets were also undertaken. (Sutton-Jones 1985, 108).

The most successful, and long-enduring, explosive signal was a tonite charge with detonator. This aid proved to be workable at off-shore light stations since machinery was not needed. The device was attached to the gallery of the lighthouse and then periodically detonated. Edwards refers to the aid as a rocket or sound-rocket. (Edwards 1884, 164-165). From a vantage point of sophisticated aids it may seem a primitive aid yet it was effective in an earlier era. (Sutton-Jones 1985, 108-109). Acetylene gas guns may have been employed in the US in the early 20th century but they may have had a short lifespan and only of limited usage (USCG 1953, 25-2).

Many of the fog signals associated with the 1870-1920 were developed before 1870 (including whistles, sirens, bells, reed horns) if only by a few years. Which suggests most of the usage of these signals falls into that 1870-1920 time. Wheeler notes that these forms reached a

state of perfection by 1870 which further suggests their zenith in commonality was in the later 19th century. (Wheeler F-1990,11).

The Industrial Revolution and its development are reflected in propulsion systems for fog signals. Many of the earlier aids required steam propulsion requiring on-site machinery including boilers that required large amounts of coals. (Le & We 2000, 109). Gradually air compressors were employed for various aids and the use of steam declined. In the early years of the 20th century electricity began to be applied to many fog signals. In some instances electricity activated air compressors. Gradually aids such as electric bells and electric sirens were directly mobilized by electrical currents. (DeWire, 1987, 171; USCG 1953, 25-2).

John Courtney invented the whistle or whistling buoy in 1876. Many of these buoys were activated by action of the sea. Unlike the fixed version, such sound buoys have remained in use. The original principle of a tube extending through the buoy float with sea-action pushing air up the tube and activating a whistle remains intact. (Wheeler 1986, 12).

Quite possibly the most important fog signal to be developed was the diaphone. The diaphone was invented in Canada in about 1900 . It was first utilized in 1914 in the US. (Wheeler F-1990, 13). It found usage in other fog-bound nations including UK. A variety of diaphone types were produced including some extremely large units. The antecedent of the diaphone can be traced to a pedal stop for a church organ. It was high in volume, reliable in emissions, and notable for its harmonic quality and less jarring on the human ear. (Searles 1984 *H & W*, 4). The diaphone is technically known as a reciprocating siren. (Barry [Searles] *H & W*). The diaphone has generated intense loyalty down to the present despite the near extinction of the diaphone.

Gong buoys were not introduced until 1921. This buoy consists of several nearly saucer-like discs arranged horizontally and activated by tappers mounted on the

superstructure of the buoy creating a sound that is very distinctive. (Wheeler F-1990, 12). The gong, in itself, is an older aid employed in lightships. (Edwards 1884, 156-157). Wesler describes a bell buoy employing two bells that was established in 1888 in New York harbor. The bells produced a kind of "chime effect" as the bells sounded off together part of the time but separately at other times. This was regarded at the precursor of the gong buoy by Wesler though the gong buoy did not materialize for nearly forty years later. (Wesler *NEJ* 1966, 1022-1023).

Fog signals are well known for the erratic reception of their emissions. Air currents are not stable and sound signals can be nearly inaudible in some conditions while long range in other conditions. Water is a much more reliable medium for passage of sounds. Since the earlier 19th century underwater sound experiments had been carried out. In 1901 the Submarine Signal Company perfected the submarine bell. The bell began in UK then migrated to the U.S. in 1906. (Wheeler F-1990, 16; Putnam 1933, 234).

Several versions were developed included models attached to lightships and buoys. A third form was mounted from a tripod on the sea bottom. Electric cables supplied an energy source that activated the bells in some instances while sea action activated other forms. Microphones on the bow of a ship coupled with telephone style receivers allowed the ship crew to receive the signals. (Wheeler 1990, 16; Nelson). In 1914 a submarine oscillator was introduced (known as the Fessenden Oscillator; Fay 1963, 12-13). This consisted of an underwater diaphragm fog horn and this was regarded as an improvement over submarine bells. Submarine signals continued until approximately the beginning of World War II. (Wheeler F-1990, 16). Both aids were listed as obsolete by USCG in 1953. This suggests some units may have lasted until the early 1950s or nearly so). (USCG 1953, 25-2).

5A3 1920-2000

USCG 1953 provides an outline for fog signal

developments that encompasses the years 1920-1950. New signals in that era included a second submarine aid, an oscillator, 1925. This aid was followed by an electric air oscillator in 1928. Between 1929 and 1941 four versions of the diaphragm signals were introduced. These included air, steam and electric forms. (USCG 1953, 25-2). Wheeler 1990 notes that the diaphragm had a sound "somewhat like a diaphone horn, but considerably cheaper to build and maintain. (Wheeler F-1990, 13-14). Seemingly no other signals were introduced for many years after 1941.

A somewhat ill-defined topic is that of bell strikers. Strikers often appear in the literature though references are often to 19th century clockwork types. USCG 1953 provides ample information though it is not fully time-related. (USCG 1953, 25-2). Older makers of mechanical bell strikers were long enduring. For example, Wheeler refers to various makers from the 19th century that included Gamewell, and Stevens companies. (Wheeler S-1990, 22). Strikers of those companies were still in use in the 1950s (though the construction may date back to the 1920s and possibly earlier) (USCG 1953, 25-2). These were hand-wound units. An electric motor-driven apparatus, in use in the early 1950s, was seemingly an elderly form destined for replacement when worn out. Accumulator Gas Co. (AGA) provided two forms of strikers and seemingly these were current. One version operated on CO<sub>2</sub> gas and one on an electric solenoid. Both versions employed a piston which when activated struck the bell. (USCG 1953, 25-6, 25-7). The older forms employed a hammer that accomplished the same task.

Wheeler notes the decline of fog signals forms which begins in the 1950s. This vanishing act extended well into the 1960s. USCG 1953 lists signals that were already obsolete: hand-operated bells, cannon-guns, both submarine bell and submarine oscillator, and the acetylene gun. Other forms were declining in usage or obsolescent. (Wheeler F-1990, 14; USCG 1953, 25-2).

The decline of fog signals accelerated in the 1960s. Wheeler notes the ending of sirens and whistles before

1970. (Wheeler F-1990, 14). USCG 1953 lists the steam diaphragm horn as obsolete and the air siren as "declining". Diaphones were "extensive" but not current in the early 1950s but they were eliminated in perhaps the 1960s. (USCG 1953, 25-2). By 1990 what can be termed "pure tone signals" and a few traditional diaphragm signals were about all that remained. (Wheeler F-1990, 14). Though probably some sirens and bells were also in place on bridges but such signals were private aids.

What Wheeler of US Lighthouse Society and others refer to as "pure tone" signals is a newer form of diaphragm signal of an oscillator type. (Wheeler F-1990, 14). Pure tone signals are unmodulated. A simulation of horn, gong or bell is feasible though debatable it can fully emulate traditional fog signals. The Pharos company, successor to AGA and Wallace and Tiernan is a key supplier of the current sound signals. (Pharos).

Along with the vanishing of fog signals is the very term "Fog Signal." Fog Signal conjured up images of sirens on the headlands of England, or an explosive signal on a Scottish rock tower, or a diaphone in San Francisco Bay. It was the instantly recognized title for a critical aspect of safety aids.

But in the 1960s, or possibly the early 1970s, the term went into a steep decline. IALA employed Sound Signal and Audible Signal (though the term fog signal was employed within the Audible Signal chapter of IDAMN). (IDAMN 1970, 3-1-030). And for that matter, IALA has offered the view that such signals are no longer mandatory for navigation. (Wheeler F-1990, 14).

The United States Coast Guard, the largest operator of fog signals, dropped the term Fog Signal during the 1970s and switched to the term Sound Signals (cp LLPCPI 1962 and 1977). The signals remained the same (of those still in operation) and they continued to issue acoustic warnings in fog and other restricted weather conditions. Yet the new term lacked much of the meaning of the older term. It seemed to suggest a limited, even a very restricted

aid, carrying out a minor role. Sound signals now mark local harbors and entrances and offshore platforms. In a late 1990s publication the USCG termed the sound signal as an "generic term" producing "an audible signal ... ." (USCG LLPCPI 1997, xxi). But the name of Fog Signal and the traditional aids it so designated, as well the vital role it carried out for generations of mariners, was eradicated for all intents and purposes. And probably for all time.

A final aid can be included with fog signals. That is the echo board which can be termed a passive form of fog signal. This is very likely an obsolete aid. It was employed on Sacramento River, the Puget Sound and other locations. It consisted of large boards set at sharp angles. When a boat sounded its whistle the echoes resounding off the angled construction were more substantial than off a natural surface and the sound could help the ship crew to determine its position. (Putnam 1933, 232; also older USCG LL).

## 5B Road, Rail, Aero Sound Signals

### 5B1 Road Sound Signals

Sound has played a much smaller role for road safety than for marine. Yet that smaller role has substantially held over many years. Sound signals for road use are rarely stand-alone units. The sound signals, usually in a bell form, are conjoined to visual aids. In some instances the sound signals are clearly adjuncts while in other instances they are essential elements though the accompanying visual signals may have had some degree of greater significance. Railway crossings, a major location for sound signals, creates a special problem of coverage. Such signals are included with both rail and road literature. Rail sources include crossing signals because train movements intersect roadways while road sources include crossing signals because train movements are a threat to road traffic. The coverage of these aids is found with rail signals.

The multiple editions of MUTCD (US), a major TCD source, gives little attention to the bell aspect despite the inclusion of railway crossings safety aids in MUTCD. One sound signal that MUTCD has included beginning with early editions is that of Draw Bridge (or Moveable Bridge) signals in the forms of bells. (MUTCD editions). Eagle Signal in the 1940s refers to "bell-sirens" for emergency situations as well as references to bells for warning or traffic changes (Eagle Signal) though that is seemingly not an official aid.

A practice has grown up of attaching sound signals to pedestrian signals for the visually impaired though MUTCD has been very quiet on their usage. In fact, a committee of the National Committee on UTCD, has worked on the issue for over 20 years yet they have not reached a point where audible pedestrian signals can be included in MUTCD despite their increasingly common employment. (Kuemmel 2000, 40-42). Portland, Oregon installed such a signal in 1948. This is possibly the original audible signal. Such signals were not very common until

the 1980s. (Oliver *PR* 1989).

This is not, in most respects, a great era for acoustical signals. This is especially true for marine signals. But pedestrian signals display a cascade of sounds. Oliver notes that such signals "emit buzzing, whistling, beeping or chirping sounds." (Oliver *PR* 1989, 33). Portland has made use of chime sounds which have proven to be more acceptable than buzzing sounds. (Kloos 2001). In the eastern U.S. many such signals employ buzzers. In Cincinnati differentiated messages have been created by using buzzing sounds for one direction and a constant tone for the other. In the western U.S. a Japanese firm, Nagoya Electric Works, has supplied many of the signals. These give off peep-peep and cuckoo sounds (otherwise referred to as bird calls). Peep-peep often designates east-west crossings while cuckoos represent north-south crossings. (Oliver *PR* 1989, 33-37). A semiotic system has thereby been created through the use of sound. Some signals also employ tactility as a message system: "vibrotactile" devices signal pedestrian movements through touch. (Kuemmel 2000, 42).

### 5B2 Rail Signals

Sound signals while seemingly a restricted area for railways, nevertheless has had a multifaceted role for over more than 150 years. Sound signals include detonators laid on tracks, flares, cab signals, railway crossings bells and gongs, and a variety of more limited applications.

#### a) Explosives

The English, though less fixiated on firearms and other explosive devices than Americans, have, nonetheless, shown a penchant for explosive safety aids. UK lighthouses have made significant use of explosive fog signals. (Ch 5A). This is also true of railway signals.

E.A. Cowper in 1841 invented a small device for use in foggy weather. It consisted of a small, flat tin case with lead "ears" containing gunpowder and matches. (Vanns

1997, 11). When the detonator is placed on the track and is then run over by a train it generated a loud bang (colloquially known as a "Banger"). (Jackson 1992, 17).

Detonators are known as torpedoes in the United States though they are seemingly identical in composition. Detonating signal serves as an alternate term. (Dempsey 1855, 393). Hollingsworth remarks that Detonator is "English English" for torpedo. (Hollingsworth 1983, 42). Not infrequently the explosive charge was termed a Fog Signal. And often, the detonator was placed on the tracks during fog, snow because of the blinding of visual signals. It was a regular aid with signal crews placing the detonators on the tracks near signals as a matter of course. In some instances the train crew placed detonators behind the train. Vanns notes that the Kynoch & Company produced nearly 300,000 detonators per week. (Vanns 1997, 10-11). Seemingly this aid has changed little since its invention.

Detonator messages followed a standardized pattern in at least some systems. In South Africa a single exploded detonator indicated the train in question was to reduce speed, and to be prepared to stop. Two indicated stop but then proceed with caution if line was clear. Three called for a full stop until approval to proceed was given. (SA TWA 1964, 61). In the US a reverse pattern of messages: danger was indicated by one explosion while caution was denoted by two. Dempsey quoted a railway source that noted a single detonator was always a danger signal. (Dempsey 1855, 393; New System 1884 *RG*, 785). Germany seemingly employed a single detonator with the message of train to stop which corresponds to UK practice. (Technical Regulations 1873 *RG*, 379).

A report of the International Union of Railways in the mid-1960s indicates the enduring character of detonators. Only a few railway systems found the detonators not adequate. Most systems found them satisfactory though numerous systems were interested in different ways to achieve the results. (IUR-ORE 1964 Abstract).

A related aid was the fuzee which seemingly is an

equivalent of the flare. Its use was employed in the train order system (UK) or time interval system (US). It was a form of chemical fire and the fuzee could be thrown off the train or inserted in the ground (RSD 1911). Hollingsworth, known for colorful phrasing, notes that a train observing a fuzee ahead "must run rather cannily..." (Hollingsworth 1983, 42)

#### b) Cab Signals & Related Signals

Cab signals may well suggest visual aids. That is substantially true though frequently there is also a sound dimension in cab signalling. However, a variety of early signals in the cab were acoustical without the accompanying visual signals. Possibly the earliest such signal was on the Nord railway in France in 1872. Train brakes and the sounding of whistle were activated when there was contact of train with a "crocodile" (sheets of metal that supposedly suggested the shape of that animal) installed on the track occurred whenever a train passed signal at danger. (Henry 1942, 165).

An early UK system, also in 1872, activated a gong if the signal passed when at danger. (Vanns 1997, 129-131). In the following year a patent was taken out for activating a locomotive's whistle if signal passed at danger; a gong was also sounded. (Vanns 1997, 129-131). The most cited sound-only signal was the early ATC (Automatic Train Control) system of Great Western Railway in 1906. (Nock 1978, 779, Blythe 1951, 106). According to Vanns a bell went off when the signal was at clear or at danger; in the later case brakes became activated. Taylor instead claims bell sounded for clear but a klaxon emitted its warning if signal passed at danger and brakes activated. (Vanns 1997, 129-131; Taylor 1949, 51). Simon notes that ATC was really an automatic train stop system (ATS) rather than an ATC. (Simon 1986, 200). A different form of message was the warning hooter of the Strowger-Hudd system in 1931. A short blast denoted clear while a continuing transmission denoted stop and continued until action was taken. (Vanns 1997, 129-131).

The US ICC promoted ATC in the early 1920s which led to cab signalling. These were visual systems accompanied by whistle that sounded whenever system "went to a more restrictive indication." (AAR1953, 153; B & M 1981, 161). Armstrong in remarking on cab signals notes the whistle is continuously sounded when reduction in speed required while a short blast is sounded when speed increase is authorized. (Armstrong 1957, 15). GRS company publications indicate whistle for restrictive actions only. (GRS 1951, 1954, 604). Taylor in 1949 speaks of the use of bells for "less favourable" aspect for coded continuous cab signalling system. (Taylor 1949, 54).

There are fragmentary and occasional entries in the literature for other sound systems. Jackson, for example, refers to fog gongs. These are electrified units affixed to the posts of signals which sound off in foggy conditions in order to prevent train crews from running past a signal at danger. Date and extent of the aid is not given. (Jackson 1992, 106). Blythe describes an early sound signal which apparently was in use before 1900. It was a metal contrivance that connected with an engine setting off its whistle in order to alert the train of an upcoming signal. This was perchance an infrequently used aid. (Blythe 1951, 104). Blythe also includes a entity known as a "Reliostop". This was an early train stop device of considerable complexity involving both sirens and whistles. But it was little employed. (Blythe 1951, 105). German State Railways employed a "Railophone" before 1914 though it is unclear if sound signals were involved. (Blythe 1951, 105-106).

### c) Crossing Signals

Sound (and visual) signals at railway crossings (termed level crossings in Europe and much of the eastern hemisphere) are of interest to both rail agencies and road safety organizations. Such signals are more directly tied to railways since that is the point of activation. Standards and guidelines are more often generated by railway sources than from road. Highway grade crossing warning devices can display diverse yet interconnected devices: bells, gates,

light signals, signs. Sound devices are of primary interest here.

The development of the track circuit permitted automatic aids at crossings. In the beginning they consisted only of bells. Supposedly enclosed cars made the sound signal of limited value (though of use to pedestrians) and visual aspects were added. Yet bells continue to be part of crossing protection. (AAR1953, 3). Sound-only signals were common up to 1920 but seemingly not after that point. (REAMC 1948, 1109). The original crossing bell (automatically controlled) was established in 1889 by American Signal Company. The first "Wig Wag" ("Autoflag") was first employed in 1914 by the Bryant Zinc Co. Both of these signals may have been sound in nature without lights though the Wig Wag displayed signs (AAR does refers to a lighted wig-wag). (WRSC). What Western Railway Supply refers to as "The Model 10" was installed in Harvey, Illinois. Model 10 is now very familiar with signs, gates, lights. Whether or not that first model contained bells is unclear though bells because a standard element. (WRSC). Phillips 1942 notes bell-only signals are becoming obsolete which suggests some still remained in use. That source notes that bells were removed in residential districts because of the irritation caused. This has also been the case in marine navigation though fog signals are many times louder than crossing bells unless those early models were far louder. One might have thought locomotives with their whistles would be much louder than crossing bells. (Phillips 1942, 206).

Bells are employed in the western hemisphere and in other areas including Australia where similar or identical signals are employed. (Westinghouse BAS). Numerous European nations include sound signals. Frequently they are described as audible warnings without specifics on the type of sound-producing mechanism. Luxembourg includes both bells and gongs. (Middelraud ERS 1995, 347-348). Alkmaar works in The Netherlands produces bell signals. (Alkmaar). Both UN 1949 and UN 1968 include sound signals for railway crossings. Seemingly, there is no mention of specific forms. Sound signal information has a

largely contemporary appearance though a hint of the past is seen in UN publications dating back to the 1960s and before that to the 1940s. Both UN conferences include mention of sound-only signals are regarded as appropriate in some instances. (UN 1949, 107; UN 1968, 98).

Gongs are a separate aid for marine aids to navigation. However gongs are at times referred to as part of crossing bells in the literature. One source even refers to a "gong type of bell". (King 1921, 302-303). The possible confusion may stem from the saucer-shaped metal disk that is often employed. That shape is often perceived to be a gong while a cup-shaped form is a bell. Bells employing a gong-shaped disk often refer to gong and bell in reference to one aid. Bells with a more familiar bell-shape are often referred to as a locomotive type of bell. That description stems from the borrowing of locomotive bells for crossing signals. (RSD 1911, 312-313; also WRSC).

#### d) Other Signals

Historic track indicators (discussed in Part F) are an obsolescent or simply obsolete aid. At an earlier date a variety of US railways provided visual/sound signals that provided warnings of approaching trains for track crews. The indicators though very much a visual aid included bells. (Hall Signal, Part F). Despite their apparent demise a modern form has developed in Europe. ERS details various systems under the heading of "Staff Warning Systems." Some forms are lighted while some are sound-only. One form, Train operated warning system (TOWS) provides fixed audible signals along the track. While the Inductive loop warning system (ILWS) is a portable system that can be carried and set up near loops placed underneath the tracks. The loops received messages of on-coming trains and thereby activate the sound signal. While this is newer technology it provides warnings akin to much older signal forms. (Hammargren ERS 1995, 359).

#### 5B3 Aero Signals

Fog Signals for Airplanes? That seems to be a very

unlikely possibility yet such an aid existed; though not labelled as a fog signal. The aid was intended to be an aid to blind flying and landing. It was known as the "Sonic Marker Beacon." It was comprised of three whistles (all high-pitch, 3000 cycles) set within megaphones and mounted on an air compressor. It was not an eccentric home-made notion but instead designed and built by the G.E. company. The signals could be heard 2000 feet in the air and 700 feet beyond the airport boundary. The individual whistles merged into one signal when a plane was equally between two of the units. The use of radio beacons accompanied by the sonic beacons was viewed as an advance toward blind flying possibilities. However, there is little other mention of the aid in the literature including the fate of the aid which was presumably short-lived. (Sonic Marker Beacon SA 1933, 32).

Sound signals continue to be employed for aviation. However, the translation of electronic signals into audio (as well as video) energy forms comes at the receiver end and is not a safety aid in itself. Such audio message receptions can include older aids such as Sonnet during and after World War II in which audio messages were in the form of Morse Code signals (Blanchard 1991, 312) and in newer aids including marker beacons (ILS) that create double messages of color light messages and Morse Code messages. (US AIP 1990, COM 0-9).

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