MLS Ground Stations - Archived 9/98

Outlook

- In development and production for international users
- Was to replace ILS but FAA switching to GPS technology
- Some European support remains, but GPS and Free Flight may become more popular
- Program future uncertain
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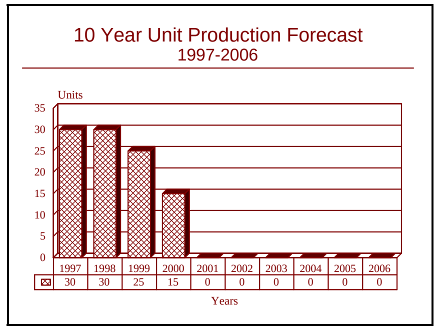

Orientation

Description. The Microwave Landing System (MLS) was intended to replace conventional Instrument Landing Systems (ILS) and Precision Approach Radar (PAR).

Sponsor

Department of Transportation (DOT)
Federal Aviation Administration (FAA)
Washington, DC
USA
(Original Program Manager)

US Air Force
Air Force Material Command
Electronic Systems Center (CESC)
Hanscom AFB, Massachusetts (MA)
USA
(Leader, Tri-Service MLS Program)

International Civil Aviation Organization (ICAO)
Montreal
Canada
(Arbiter of International Civil Aviation Standards and Regulations)

Radio Technical Commission for Aeronautics (RTCA)
Washington, DC
USA
(Federal Advisory Committee)

Contractors

Alenia SpA
Rome
Italy
(Hazeltine licensee, member of CNI consortium)

AlliedSignal Commercial Avionics Systems
2100 NW 62nd Street
Ft. Lauderdale, Florida (FL) 33309
USA
Tel: +1 305 928 2100
Fax: +1 305 928 3000
(formerly AlliedSignal, Bendix Comm Div)
(Ground stations)

ARINC Research Corp
2551 Riva Road
Annapolis, Maryland (MD) 21401
USA
Tel: +1 401 266 4650
Fax: +1 401 266 4049
(USAF support, system assessment of Tactical MLS)

Ausrire Institute
St. Petersburg, Russia
CIS
(CIS MLS R&D house)

Canadian Marconi Company Aerospace
415 Leggett Drive, PO Box 13330
Kanata, Ontario, K2K 2B2
Canada
Tel: +1 613 592 6500
Fax: +1 613 592 7427
(Originally Hazeltine licensee, now developing own ground station technology)

Compagnia Italiana Servizi Tecnici SpA (CISET)
Rome
Italy
(Member of CNI consortium)

ENA Telecomunicaciones SA
Madrid
Spain
(Signed agreement with Interscan to jointly develop, manufacture and market MLS equipment)

GEC plc
GEC-Marconi Defence Systems
Silverknowes, Ferry Road
Edinburgh, EH4 4AD, Scotland
UK
Tel: +44 131 332 2411
Fax: +44 131 343 5050
(Licensee to Micronav, cooperating in developing current MLS-400 up to Category 3 standards)

GEC plc
GEC-Marconi Electronic Systems Corp
164 Totowa Rd, PO Box 095
Wayne, New Jersey (NJ) 07474-0975
USA
Tel: +1 201 633 6000
Fax: +1 201 633 6578
(TPN-30 ground station)

Industrie Face Standard
Milan
Italy
(Designed, developed and built first Italian DME/P, member of CNI consortium)

Interscan International Ltd
Rydalmere
Australia
(Australian ground station, providing antennas for Wilcox, agreements signed with Italtel and ENA)

Italtel SIT SpA
Milan
Italy
(Marketing agreement with Interscan covering Italy and neighboring countries)

Japan Radio Co, Ltd
Tokyo
Japan
(Ground station)

Micronav Ltd
Sydney, Nova Scotia
Canada
(Ground stations)

Nippon Electric Co (NEC)
Tokyo
Japan
(Sendai MLS; MoU with Hazeltine for exchange of MLS data)

Norsk Marconi AS
Oslo
Norway
(Marketing and MLS development agreement with Hazeltine)

Phillips SpA
DCS Division
Rome
Italy
(Hazeltine licensee, head of CNI consortium set up with CISET, Face Standard, and Alenia to market MLS)

Racal Avionics Ltd
88 Bushy Rd
London, SW20 OJW
UK
Tel: +44 181 946 8011
Fax: +44 181 946 7530
(Bendix licensee)

Raytheon Co
141 Spring St
Lexington, Massachusetts (MA) 02173
USA
Tel: +1 617 862 6600
Fax: +1 617 860 2172
(MMLS Test systems)

Siemens Plessey Systems
Oakcroft Rd, Chessington
Surrey, KT9 1QZ
UK
Tel: +44 181 397 5171
Fax: +44 181 391 6196
(P-SCAN 2000 ground station)

Standard Elektrik Lorenz AG (SEL)
Stuttgart
Germany
(SETAC landing aids, DME-based ground station, Bendix licensee)

TAU Corp
Los Gatos, California (CA)
USA
(MLS/GPS combination unit development)

Textron Inc
Textron Defense Systems
Wilmington, Massachusetts (MA)
USA
(TPN-45 MMLS)

Thomson-CSF, Radars & Countermeasures
La Clef de Saint-Pierre - 1, Blvd Jean Moulin
Elancourt Cedex, F-78852
France
Tel: +33 1 34596000
Fax: +33 1 34596342
(MLS 800, 810, 840 and SATRAM ground stations, cooperating with Brazil in developing ground stations for small airfields)

Thomson-CSF
MEL Division
Crawley, England
UK
(MADGE MLS; Hazeltine MLS licensee)

Thomson-CSF
Telecommunications Radioelectriques et Telephoniques (TRT)
Paris, France
(Developing ground station)

Thomson-CSF
Wilcox Corp
Kansas City, Missouri (MO)
USA
(Ground stations)

Toshiba Corp
Tokyo
Japan
(Japanese CAB MLS evaluation at Sendai Airport, assisting NEC; Bendix licensee)

Status. Various ground stations are in development and production; some are currently commercially available.

Total Produced. An estimated 155 were delivered worldwide through the end of 1996, although not all may be in service.

Application. MLS facilitates precision approach landings, especially in difficult Category III landing sites. It was originally meant to replace ILS ground stations worldwide; however Global Positioning Satellites will now almost certainly usurp that role.

Price Range. We are using a base figure of US$1.5 million per Category III installation (based on an Interscan system), and US$850,000 per Category I installation (based on FAA order to Bendix).

Technical Data

Design Features. The ICAO MLS is an air-derived system in which ground equipment transmits position information signals to airborne receivers. The position information gives vertical and horizontal angle coordinates and a range coordinate. Angle information is derived by measuring the time difference at the receiver between successive passes of highly directive, narrow, fan-shaped beams. Range information is provided by improved DME (Distance Measuring Equipment) elapsed-time-of-responding-signal measurements.

The time-reference scanning beam (TRSB) signal format is time-multiplexed, providing sequenced information on a single carrier frequency for all angle functions (azimuth, elevation, flare, missed approach), and includes a time slot for 360-degree azimuth, as well as provisions for adding additional functions. A versatile ground-to-air data communications capability is provided throughout the angle coverage volume by stationary sector coverage beams which transmit the identity of each angle function, using DPSK (Differential Phase Shift Keying) modulation, and which provide growth potential for additional information. The channel plan provides 200 C-band channels at 300 kHz spacing between 5031 MHz and 5091 MHz (according to the FAA's spectrum engineering department head, the area between 5000 and 5250 MHz has been set aside for MLS transmissions for the next 13 years). The D-band DME/P also provides 200 channels between 960 MHz and 1215 MHz. Digital techniques are used to generate the scanning beams, monitor the equipment and process the guidance signals, enhancing the stability of the signal in space.

One of the most troublesome problems is self-interference from signal reflections (multipath error). The narrow, fan-shaped azimuth beam scans horizontally with a vertical pattern shaped to control illumination of the airport surface; the elevation beam is shaped to minimize radiation toward the airport surface. The narrow beams (to distinguish direct from reflected signals) and the antenna pattern shaping (to limit the amount of signal energy radiated toward reflecting objects) help solve the multipath problem on the ground and permit relatively simple airborne processing. This is a principal advantage of the phased-array TRSB system over Doppler systems.

Rapid beam scanning provides a high data update rate: 13.5 Hz for azimuth and 40.5 Hz for elevation. This allows integration (smoothing) of individual measurements, providing guidance information with a very low noise content. Narrow system bandwidth accommodates the Doppler shifts caused by aircraft motion relative to the station over a range of approach speeds from hover to 600 knots. Coverage is provided to a minimum range of 20 nm and to 20,000 ft. Azimuth stations provide coverage of right/left 10☜, 40☜ or 60☜, depending on selected configuration. Elevation stations provide coverage from 0.9 degrees to 20 degrees. Both antennas can be located on the same pad, and MLS can be collocated with ILS during transition.

The phased-array antennas are controlled by a beam steering unit using digital circuits to generate commands for each phase shifter. Modular design permits altering antenna beam width by replacing printed circuit cards. Azimuth antennas employ waveguide column radiators with sharp lower edge cutoff to minimize ground interaction. Elevation antennas employ a passive coupling network, minimizing the required number of phase shifters and maximizing low angle performance. The parallel arrays provide inherent redundancy and experience little degradation from a number of independent component failures (“fail soft”). The compact MLS antenna arrays are enclosed in weatherproof radomes equipped with de-icers and maintained in a temperature- and humidity-controlled environment. Extensive internal, integral, and field monitoring is provided. Design standards call for MTBF exceeding 4,000 hours – more than twice that of an ILS system.

Modular concepts, applied at all levels of system design, facilitate tailoring individual installations to local requirements. Three major system configurations are presently identified: basic, expanded and small community. The basic configuration includes the approach azimuth, approach elevation, and DME/P transponder subsystems. Expanded configuration adds missed approach and flare subsystems, and is designed with monitoring and redundancy to meet ICAO and Category III landing requirements. The small community system is designed to meet the need for Category I service, and consists of the approach azimuth and approach elevation subsystems with either DME ranging, or standard ICAO marker beacons on the approach path.

MLS ground stations are made up of the following basic components: an approach azimuth facility, an approach elevation facility and a collocated DME (Distance Measurement Equipment). The elevation facility is located (depending on the minimum glide path provided) between 400 and 1,000 feet to one side of the runway. The azimuth element and the DME are usually located about 1,000 feet beyond the rollout end of the runway, on the extended counterline. Precision Distance Measurement equipment will provide aircraft equipped with DME/P avionics final approach accuracy to within 100 feet, compared to existing facilities that provide only 1,200 foot accuracy. DME/P will be completely interoperable with existing non-precision DME airborne equipment. The MLS-DME/P equipment group also will enable aircraft to use off-set approaches where needed.

Airborne MLS equipment consists of antenna, angle receiver-processor, DME, and the associated controls and displays. Two antennas are required since the MLS radiated ground signal is more or less a pure line-of-sight beam and full 360^o reception of the ground signal. When two MLS receivers are installed in larger-sized aircraft, three or more antennas may be necessary. The processor includes extensive signal acquisition and track validation features to ensure that the angle guidance signal has high integrity and immunity from interference. Automatic self-test using BITE (Built-In Test Equipment) is employed, and an end-to- end check of the unit can be initiated by injecting a TRSB signal at the receiver input. DME/P is interoperable with DME/N (Normal DME). The DME/P interrogator can be used for en-route navigation with VORTAC; pulse shaping and enhanced signal processing provide the required DME/P accuracy for approach.

Current DME/P transponder accuracies are ±250 ft for DME/N interrogations, ±50 ft for DME/P initial approach mode interrogations, and ±33 ft for DME/P final approach mode interrogations. Civil operators feel that 100 ft accuracy is adequate; DoD is pursuing a 20 ft accuracy requirement.

Avionics output guidance can be coupled to conventional CDI (Course Deviation Indicator) or ILS indicators, or to an automatic flight control system. Additional information, including facility identification, runway azimuth, landing category, runway identification and condition, and minimum usable glide slope, can be presented on an auxiliary data display panel.

Operational Characteristics. The current ILS (Instrument Landing System) system used at many civil and most military airports is based on a concept that is over 40 years old, and while it is still a sound principle, it is not adaptable to many modern aircraft capable of steep approaches. The MLS makes it possible to overcome the limitations of the ILS as well as provide some additional benefits gained from the application of modern technology.

MLS is virtually insensitive to geography and obstructions. At most locations, the full $\pm 140^{o}$ scan coverage will be usable. At particularly difficult sites, the coverage can be reduced to $\pm 110^{o}$. In addition, the scan coverage can be adjusted to extend further to one side and less to the other to accommodate special approach requirements. MLS operates at microwave frequencies; therefore no extensive grading or land purchases are required as with ILS. The existing geography of any airport, large or small, requires little or no modifications for the installation and operation of MLS.

An inherent drawback of ILS is that terrain features in the runway signal area are an active part of the antenna system. Thus, to operate at optimum capability, ILS systems need an approximately 1,500-foot, relatively flat and unobstructed area at the runway approach end. This leads to ILS hold lines at certain airports to keep aircraft that are landing from receiving interference from aircraft that are taking off. JFK Airport in New York City, NY, has a problem because Jamaica Bay at the end of certain runways affects glide slope beam angles.

A significant limit on ILS installation is the availability of frequencies. MLS is capable of operations on any one of 200 channels. ILS, as it is now configured, has a maximum capacity of 40 channels.

<u>Operational Flexibility</u>. Under MLS, multiple approach azimuth and glide path guidance is simultaneously available to a variety of users. For example, large command jets, smaller aircraft, STOL aircraft, and helicopters can all carry out approaches for their specific capabilities, with MLS being especially valuable for the latter two.

An increasing number of aircraft are now being equipped with Area Navigation (R-NAV) capability. The MLS signal will provide for much broader and more efficient use of R-NAV, using segmented and eventually curved approaches.

MLS performance is insensitive to environmental and local siting conditions, with information being transmitted at the same high standard. This will provide the lowest minimums possible that are consistent with other factors such as terminal producers and aircraft/pilot capabilities.

The installation cost of MLS could be less than that of ILS, with operational costs being greatly reduced because of the system's greater reliability as well as by a feature known as the Remote Maintenance Monitor System (RMMS). In cases of failure, RMMS enables technicians to identify exactly what has failed.

Variants/Upgrades

What follows is a list of MLS ground stations known to us. The Russian R&D agency Ausrire has developed a Category III ground station, but few details are available on the system.

AlliedSignal, Bendix Communications Division (US). In December 1982, Bendix (US) won FAA approval for use of an MLS in instrument flight rule conditions. The system, approved in November 1982, serves the airport at Valdez, AK. An additional Bendix MLS Model B215-40S was selected by the USAF for runway 10 at Shemya AFB, located at the western tip of the Aleutian Islands in Alaska. A Model B215-40S was leased to the UK's Civil Aviation Authority in 1984. Bendix was to supply the FAA with two Category I ground stations for evaluation in the agency's MLS demonstration program. The contract includes options for 24 additional such systems.

Canadian Marconi (Canada). This company's MLS ground station is called the Model 2500. Coverage is $\pm 50^{o}$ in azimuth and $+0.09^{o}$ to 20^{o} in elevation. The frequency range is 5031.0 to 5090.7 MHz with 300- kHz channel spacing. Output power is 20 watts. The azimuth antenna is a phased waveguide type and the elevation antenna is a phased stripline type, both with 2^{o} beam width. The Model 2500 has a wind loading capability of up to 180 km/h (115 mph). CMC initially obtained the MLS technology through a licensing agreement with Hazeltine, subsequently investing heavily in improving the technology. The 1990 acquisition of Micronav should bring further benefits. As of mid-1990, CMC had sold, leased or was supporting 15 MLS systems for use at airports in Canada, Europe and the US.

Hazeltine (US). This company's Model 26XX A/D is available in seven different configurations, all with elevation coverage of $+0.9^{o}$ to 15^{o}. Beam widths vary from 1.5^{o} to 2^{o}. Azimuth coverage varies from ± 10 to $\pm 60^{o}$, with beam widths from 1^{o} to 3^{o}. The wind loading capability is 70 knots in the operational mode. Minimum MLS system range is 20 nm, with coverage to 20,000 feet. The Model 26XX A/D is a fourth-generation system that combines all the best features of the company's Model 2400, 2500 and 2600 MLS systems. The Model 2600 was the version being produced for the FAA Category I contract, which Hazeltine subsequently lost. As of late 1988, Hazeltine and its various licensees had installed 14 Model 2500s outside the US.

Interscan (Australia). Interscan International Ltd is owned by the Australian Industry Development Corporation. Few details are available about this company's MLS ground stations, but the company is claiming that it is leading the field in the development of Category II/III capabilities, with a Category III station already installed at Salamanca, Spain, and another to be installed in China. The company's capabilities in this area are in part derived from experience with producing secondary surveillance radar antennas and TACAN beacons for the Royal Australian Air Force. Interscan (phased-array antennas) teamed with Wilcox (electronics) in the first FAA Category I/II competition which saw Hazeltine win. Interscan is no longer allied with Wilcox due to the latter company being acquired by Thomson-CSF.

Interscan was making a major international thrust. In mid-1991 the company staged a major coup when it signed an agreement with China (Xian Research Institute for Navigation Technology) for three Category III stations, with the potential for further contracts for ground stations for 76 airports, although the Chinese may eventually upgrade as many as 150 airports. Interscan had signed agreements in 1990 with the Spanish company ENA *Telecomunicaciones* to jointly develop, manufacture and market MLS equipment, and with the Italian company *Italtel* to market Interscan's equipment in Italy and neighboring countries (possibly also to eventually include licensed-manufacture in Italy).

Thomson-CSF (UK). This British company has available the MADGE (Microwave Aircraft Digital Guidance Equipment), a 220-pound field-portable landing aid that assists pilots in landing at forward tactical sites, or aboard ships, in low-visibility conditions. The Royal Navy uses MADGE for recovery of Sea Harriers onboard its aircraft carriers. The US Marine Corps evaluated the system in 1990 for possible replacement of its precision approach radars.

Micronav Int. (Canada). The Micronav MLS features coverage of ±140^{o} in azimuth (beam width of 2^{o}) and +0.9^{o} to +15^{o} in elevation (beam width of 15^{o}). The antennas are phased arrays. The system was designed for use in harsh Canadian weather and has been installed at Toronto Island Airport, Port Hawkesbury (Nova Scotia) and Pemberton (British Columbia). Micronav became a Plessey subsidiary through the Plessey Acquisition of Micronav's parent company, Leigh Instruments. Subsequently, in April 1990 Leigh Instruments filed for bankruptcy. In September 1990 Micronav was acquired by Canadian Marconi and IMP Group.

A Micronav Model 400T ground station is being used at Aberdeen Airport, Scotland, by the UK's National Air Traffic Service in a study of advanced landing guidance system concepts. The 400T has been modified to transmit local accuracy corrections to aircraft using GPS. The company has been selected by Transport Canada to develop Cat II and III systems for Phase 1 of Canada's MLS program. Micronav has developed unique software that allows GPS course corrections to be interleaved with the 400T's normal guidance signals and transmitted at the same C-band MLS frequency.

NEC (Japan). This Japanese company's MLS ground station has a coverage of ±140^{o} in azimuth and 0^{o} to 15^{o} in elevation, with both antennas having a beam width of 1.5^{o}. The frequency band is from 5031.0 to 5090.7 MHz, with the DME/P frequency band covering 960 to 1215 MHz. The system has a 20 nautical mile range. One system has been installed at Dendai Airport.

Siemens-Plessey (UK). The Siemens-Plessey MLS P-SCAN system features ±142^{o} azimuth and +0.9^{o} to 15^{o} elevation coverage. The azimuth antenna consists of 60 radiating column elements forming a flat planar array, while the elevation antenna is composed of a vertical array of 80 radiating elements. Two Plessey systems are being used for CAA evaluations in the UK. Siemens-Plessey has now introduced the Category III P-Scan 2000 station.

Thomson-CSF (France). The company's MLS 840 features ±140^{o} proportional coverage in azimuth and +0.9^{o} to 15^{o} proportional coverage in elevation. Both antennas are phased arrays. Beam width in elevation is 1.3^{o} and 1.1^{o}, 2.3^{o} or 3.5^{o} in azimuth, depending on runway length.

Textron Defense Systems (US). Textron has developed the TRN-45 MMLS (military microwave landing system) which is rapidly deployable and allows landings at all manner of temporary bases, as well as fixed bases. The Category II system is usable with runways of up to 12,000 feet in length. The collocated version weighs less than 500 pounds, while the split-site version weighs less than 600 pounds. Coverage is ±140^{o}, with elevation of +0.9^{o} to +15^{o}, and range of 15 nm. Azimuth beam width is 2.8^{o} and elevation is 2.2^{o}. The MMLS frequency range is 5031-5091 MHz, while the DME/P frequency range is 979-1,150 MHz. The system will be operational in wind speeds of up to 75 knots (tied down).

Interestingly, the UK Civil Aviation Authority chose the MMLS for 1994 tests at London City Airport due to the required steep approaches, as well as ILS multipath signal problems caused by the density of buildings in the area. The authority had already tested the MMLS at Cardiff-Wales Airport due to the degradation of ILS localizer signals at the airport after construction work.

Wilcox (US). The Wilcox MLS features a ±160^{o} proportional coverage in azimuth, and a +0.90 proportional coverage in elevation. Beam width is 2^{o} in azimuth and 1.5^{o} in elevation. The antennas are phased arrays with microstrip radiators and vertical polarization. Minimum range is 20 nautical miles. The wind load factor is up to 100 mph (87 knots). DME/P frequency range is 962 to 1213 MHz with 252 channels. Wilcox is now a Thomson-CSF subsidiary. In mid-1990 Wilcox was awarded an FAA contract for two Category I ground stations for installation at Midway (Chicago) and JFK (NYC) airports. In June 1992, Wilcox announced it received a US$78.2 million contract award from the FAA to produce six MLS test systems.

Program Review

Background. Requirements for a system to permit safe landings under limited visibility conditions are currently met by two principal systems. ILS (Instrument Landing System) has been the world standard civil landing guidance system since 1949. GCA (Ground Controlled Approach) is the system of choice for most military services.

ILS is a VHF/UHF system in which ground antennas transmit radio beams creating a glide path as the intersection of an inclined plane (glide slope) and a vertical plane (center line), leading down at an angle of about 2.5 degrees to the runway threshold. An airborne receiver interprets aircraft position in relation to center line and glide path, displaying them on a cockpit indicator as fly left/right up/down commands. Critical distances to the runway are established by fan-shaped outer and inner marker beacon signals transmitted from small ground stations along the center line; audio and light signals announce beacon passage in the cockpit.

ILS has four major limitations:

The glide path is narrowly and rigidly defined, bottlenecking landing traffic and limiting flexible use by VTOL, STOL, and other high-performance aircraft.

VHF/UHF is a crowded band of the RF spectrum and ILS is limited to 40 frequencies — a severe handicap in today's crowded skies.

The ILS beams are sensitive to terrain and atmospheric conditions; they can, for example, be rendered unusable by snowfall or construction equipment on the airport.

The large ILS antennas require careful siting and fixed installation, and are not adaptable to tactical military use.

GCA is a radar system in which ground-based controllers vector aircraft to the runway threshold with radio voice commands. ASR (Air Surveillance Radar) controllers direct pilots to an approach gate, handing off to a PAR (Precision Approach Radar) controller who gives commands to establish and maintain the aircraft on glide slope and center line, based on his reading of a composite vertical and horizontal radar display. GCA is dependent on the controller's skill, and is inherently less accurate than ILS by the nature of human communication. It is flexible and transportable; and, being a ground-derived concept, it conforms to the military concept of traffic control. In air-derived systems, signal interpretation is done onboard the aircraft (control in the cockpit); in ground-derived systems, interpretation is done on the ground and relayed to the cockpit (control on the ground).

Interest in MLS-type systems dates back to the late 1930s when the limitations of ILS first became evident. Technology in the area of microwaves was not up to the requirements needed for a landing system, although a prototype MLS was built by MIT in 1939.

Interest in the use of the higher frequencies for landing systems continued, especially because of the better operational flexibility (both for siting and for beam shaping) and the ability to use smaller antennas and greatly reduced installation expenses. Two organizations, the Radio Technical Commission for Aeronautics (RTCA) and the International Civil Aviation Organization (ICAO) began similar studies for the definition of technical and operational requirements for a future precision landing system to be used internationally. The two organizations cooperated closely, with at least 50 different techniques (including various techniques based on microwaves) being examined to determine the best approach.

Focused efforts to develop an improved all-weather landing system began in 1967 with the establishment of RTCA Special Committee 117, although testing and development work on scanning beam approach and autoland systems was done throughout the early 1960s. The National Plan for Development of the Microwave Landing System, based on SC-117 recommendations and published in 1971, provided a structure to coordinate efforts by NASA, DoD, and DOT/FAA. Although the FAA played the lead role throughout the tortuous history of this program.

The broad objectives established by RTCA SC-117 were:

(1) to provide a high-integrity precise signal in space, which is insensitive to a physically dense airport environment

(2) to permit all-weather operations with an extremely high degree of safety

(3) to provide for a common civil/military system in accordance with national policy

(4) to provide for low-cost versions permitting the extension of economical service to low-density airports

(5) to meet the needs of V/STOL aircraft for approach and landing services

(6) to provide a flexible guidance system, aiding in noise abatement and providing the capability for curved approaches to runways as a means to increase airport capacity

(7) to permit reduced separation of parallel IFR runways

(8) to provide compatible tactical military versions of the system

(9) to provide a system design that would be internationally acceptable as a replacement for the ICAO standard VHF/UHF ILS

These recommendations became the basis for the July 1971 *National Plan to Develop a New Microwave Landing System (MLS).*

The plan envisioned six system configurations. Basic MLS was to satisfy civil and some military fixed base, Category I and Category II needs. (Basic Wide was a wide-aperture system with a narrow beam for high accuracy; Basic Narrow, a narrow-aperture system with a wide beam and less accuracy.) Expanded MLS would meet Category III needs with flare and missed approach subsystems, special monitoring, and redundancy. Small Community was a design-to-cost MLS to provide service for small operators. Shipboard MLS required compensation for ship motion, and was contemplated as a replacement for the current ACLS (Automatic Carrier Landing System). Requirements were also established for a Joint Tactical MLS and an Air Transportable version of the JTMLS.

(Note: Category I, II, and III landing conditions are defined in terms of decision height (DH) and runway visual range (RVR), and measures of the weather conditions under which the pilot must be able to assume visual control of the landing approach in order to continue. Category I weather minimums are 200 ft DH and 1/2 mile RVR; Category II, 100 ft and 1/4 mile; Category IIIA, 0 ft and 1/8 mile; Category IIIB, 0 ft and 1/16 mile; and Category IIIC, 0 ft and 0 miles.)

System development was structured as a three-phase program to explore all technology applicable to MLS development and select only the most promising approaches for engineering development before choosing an optimum system for full-scale development. The Phase II contracts in FY73 went to Bendix and Texas Instruments (conventional scanning beam systems), and to Hazeltine and ITT (Doppler scanning systems), eliminating the other two Phase I candidates, Raytheon and AIL/Collins. Phase III awards to Bendix and TI in 1975 signaled consensus on TRSB MLS as the US candidate for ICAO approval as the new international standard.

Abroad, other candidates were being groomed. Germany developed the sector-TACAN system (SETAC), compatible with NATO standard TACAN. Ground equipment consisted of either fixed or mobile SETAC-A (azimuth and DME/P) and SETAC-E (elevation) stations, providing center line, glide slope, and range information to the pilot once he positioned his aircraft within 25 degrees of the approach track using TACAN. The aircraft required a SETAC supplement to normal TACAN equipment and a control unit. Angle information was derived from phase difference measurements. SETAC provided Category II landing capability; it was adopted by NATO as an Interim MLS (I-MLS), and has been in active service with the German Air Force. France initially advocated an L-band data link system combining communication and navigation functions. Italy's Elettronica offered an ingenious ground-derived system, LEA (Landing at End of Approaching). LEA derived both angle and range data from signals transmitted by the aircraft, using interferometric techniques; the derived information was rebroadcast to the aircraft.

NATO developed its own set of constraints, generally favoring ground-derived systems – mobility, adaptability to shipboard installation, inclusion of the air traffic control function. In the international civil arena, the (then) USSR weighed in with a scanning beam MLS much like the FAA candidate. Interscan, backed by the Australian Government, was developing the TRSB MLS concept ultimately adopted; the former joined Wilcox Electric in 1979 in cooperative development efforts. Noting the urgent need for improved approach facilities at mountainous Pemberton Airport in British Columbia, Micronav of Canada built and installed there an MLS tailored to the De Havillland DH-7 STOL aircraft; the approach is a dogleg and the glide slope a steep 7.5☜. The British developed a Doppler MLS based on airborne measurement of the received frequency differences between shifting and reference signals transmitted from the ground.

In the US, a great deal of flight testing was being done, primarily at the FAA NAFEC (National Aviation Facilities Experimental Center) at Atlantic City, New Jersey, and the NASA/Ames facility at Crows Landing, California. At this time Hazeltine pulled off a coup. In a Navy-funded feasibility demonstration, COMPACT (Cost Minimized Phased Array Circuit), the company developed a small phased- array antenna, usable with either Doppler or scanning beam systems. This proved to be the key to Hazeltine's eventually winning the FAA contract.

TRSB Wins. The gunfight at the ICAO corral came on April 19, 1978. An earlier straw poll of AWOP, the ICAO All Weather Operations Panel, produced a deadlock between the Australian/US TRSB MLS and the UK Doppler MLS. Then came the 1978 Montreal meeting of ICAO's All Weather Operations Division, the largest of its kind ever held, with 254 attendees from 73 countries. In a secret ballot, by a vote of 39 to 24 with many abstentions, the Australian/US TRSB MLS became the new international standard.

With the development of the National Airspace System (NAS) plan in 1981, MLS was incorporated as one of the major system projects, and an MLS implementation strategy was integrated into the NAS plan.

Hazeltine Contract. By the mid-1980s attention focused on the FAA acquisition program for about 1,250 MLS ground stations. As 1983 ended and the first award (178 systems) drew near, three contenders remained: Hazeltine, Allied/Bendix, and the team of Northrop/Wilcox and Australia's Interscan. In January 1984 DOT announced the FAA award of a US$90.6 million contract to Hazeltine for 178 MLSs, to be delivered over a five-year period starting in the summer of 1985. The first units, announced DOT, would be installed in Boston, Massachusetts; Denver, Colorado; the state of Alaska; and Washington, DC; plans to have 1,250 units installed by the year 2000 were affirmed. In April 1984 the world's first unrestricted operational MLS, a Hazeltine system, was commissioned at Cadillac, Mississippi. Several Bendix systems were also installed, including two difficult approaches at Valdez Airport and Shemya AFB, Alaska.

Following the best traditions of the program, Bendix publicly contemplated a legal challenge to the Hazeltine award, claiming the bidding had been reopened after "best and final" offers were received. Hazeltine acknowledged pursuing an "investment strategy" in bidding for the first lot, at a loss of at least US$12 million. Estimates of the ground station market at that time were: FAA procurement, 1,250; other US airports, 500; US military, 500 fixed base and portable; rest of the world, 2,500. Dollar estimates ranged from US$2 billion to US$4 billion. Passions cooled, and everyone announced plans to remain in the long competition for the other 4,572 ground stations.

Problems Appear. By early 1985, the FAA was projecting nine-month delays in MLS deliveries. "Software difficulties" were blamed; Hazeltine had substantially underestimated the programming tasks. In early 1986 the Aircraft Owners and Pilot's Association (AOPA) issued a statement calling on the FAA to stop procuring MLS and instead go with a limited, less costly upgrade of current ILS systems. A primary concern expressed was whether general aviation aircraft owners would be able to afford MLS receivers. The AOPA also claimed that the FAA's rationale comparing the reliability of MLS versus ILS was faulty, since the MLS is solid state, while the ILS is based on tubes, now an antiquated technology. The AOPA claimed that antenna gains and the use of solid state electronics could make ILS the equal of MLS.

In a letter to the FAA, the president of AOPA recommended that those MLS ground stations presently under contract for installed at international airports, heliports and those few other such facilities where ILS cannot be used and which qualify for precision approaches to be installed. The funds budgeted for MLS expansion would then go to the replacement of deployed tube-type ILS systems with advanced solid state ILSs that would include up-to-date antennas, remote monitoring, and modular construction. General aviation industry sources estimated that there would be about US$1.4 billion saved in MLS airborne receiver purchases and related costs alone for owners and operators of the approximately 110,000 US general aviation aircraft equipped for instrument landings.

About the same time, the National Business Aircraft Association took exception to the FAA's installation plan. According to the NBAA, over 90 percent of the initial MLS locations would be on runways or airports currently served by ILS, thus offering little improvement in capability for the funds expended and little incentive for aircraft owners to install MLS receivers. A survey of NBAA members turned up a list of 484 different runways they claimed would "immediately and directly" benefit from MLS installation. Only 38 of these were on the initial FAA installation list.

However, in October 1986, the FAA issued a statement that it planned to continue with its MLS procurement in spite of opposition from such groups as the AOPA and the fact that there was a delay of at least 18 months in deliveries of the first ground stations. The FAA cited a particular advantage of MLS over ILS, that ILS has to be constantly recalibrated, even for minor incidents such as a bird defecating on the antenna.

In mid-1987 the FAA made another policy change and agreed to install up to 100 new ILS units at various airports across the US. However, the rationale used was the need to ease the overcrowding of the skies since deregulation.

At about the same time, the chairman of the Regional Airline Association (RAA) came out strongly in favor of

MLS systems, and even said that the RAA planned to ask the FAA and Congress to change the deployment criteria to include smaller airports. The RAA had already passed a resolution supporting full implementation of the MLS program. Primary reasons cited for supporting MLS included safety enhancement and increased landing capacity.

From then on, the debate increasingly against MLS. The Air Transport Association (ATA) had been one of the original proponents of the fielding the systems. However, as time passed, the association became one of the major critics of the system. The ATA was particularly concerned about the following: whether the purported shortage of FM frequencies with for ILS was actually true; whether MLS had to be used for curved and segmented approaches, and whether MLS actually increased the capacity of, or reduced delays in, airspace that included several busy airports (New York for example). The ATA felt the FAA was not properly addressing these issues in its evaluation plans and recommended the evaluations be modified to address these perceived shortfalls.

In mid-1990, the International Aircraft Owners and Pilots Association (IAOPA) submitted a report to the US Congress calling for the abandoning MLS, as well as the Mode-S surveillance radar, in favor of satellite-based navigation systems. Lower cost and higher flexibility were cited as the two main advantages for going to satellite-based systems.

Hazeltine Contract Yanked. On August 7, 1989, the FAA announced that it was canceling the Hazeltine contract. The prime cause cited was that of the 178 ground stations originally scheduled to be delivered by the end of 1988, only two had been delivered as of mid-1989. The FAA had issued a show-cause letter on June 2, 1989. According to the FAA, Hazeltine's June 23rd response to the show-cause letter did not offer any reasons why the FAA should not terminate the contract. Subsequently, Hazeltine requested and was granted a “standstill” moratorium period in order to pursue the potential for a third party to purchase Hazeltine's MLS product line, but no successful candidate appeared and the moratorium expired August 4th. Hazeltine claimed that it was unable to meet the production requirements because of massive changes made by the FAA in the contract, and FAA “maladministration” of the contract. Ironically, both the FAA and Hazeltine agreed that Hazeltine met all technical requirements and that performance of the ground stations was not an issue.

ATA/FAA MLS Evaluation. In late 1991 a three-year evaluation of the efficacy of MLS was brought to a close with a qualified endorsement of MLS. The evaluation was carried out by an Industry MLS Evaluation Task Force of airspace users created at the behest of the ATA, whose conclusions now will be examined by the ATA board of directors. The ATA had challenged the efficacy of Category II/III MLS considering the improvements in ILS antenna technology, as well the high cost of fitting airline fleets with MLS receivers. Also examined was the viability of what is now called the GNSS (Global Navigation Satellite System), the combination of NAVSTAR GPS and GLONASS navigation satellites (a Russian constellation) that is expected to provide near-Category I capabilities, and even perhaps Category II with appropriate avionics. The task force agreed that a combination of MLS and GNSS offered advantages for terminal operations.

However, there was uncertainty about the utility of GNSS because of doubts over whether the GLONASS system would ever be fully deployed. The full GPS and GLONASS deployment would be required in order to ensure complete and reliable ATC coverage, although not all of the GLONASS constellation may be required. The GLONASS satellites would also need to be replaced on a regular basis due to a relatively short lifespan of only one to two years, and the ability of Russia to maintain the system was in doubt. Such doubts were put to rest with the December 1995 completion of the Russian GLONASS system. The final two satellites of the 24-satellite constellation were placed in orbit, and the system became operational in 1996.

FAA Approach Restructured. With the problems caused by the complaints raised by various organizations and the demise of the Hazeltine contract, the FAA restructured its approach and conducted an evaluation program that was mandated by the Secretary of Transportation (as the result of a GAO analysis of the MLS program). The objectives of the projects proposed for execution under this plan were to go beyond the limited purpose of evaluation and demonstration. Rather, the projects would provide the basis for a production go-ahead decision, for the early implementation of MLS to increase airport capacity and reduce traffic delays, and to demonstrate the economic and technical benefits to the aviation community and the Congress.

This evaluation program included the following elements: analysis of the available ILS frequencies for the expansion of precision approaches in the US; the evaluation of wide-body aircraft curved or segmented approaches and other advanced technologies for precision approach; the evaluation of advanced procedures in multi-airport environments; general aviation/capacity enhancement; comparison of MLS to ILS performance; assessment of MLS avionics installation costs; assessment of reduced MLS minimums; development of DME/P interrogators; and Category II/III flight demonstration. The operational

Service Test and Evaluation Program (STEP) was completed using prototype equipment at a number of appropriately typical locations.

According to the successor to the NASP, the December 1991 edition of the *Aviation System Capital Investment Plan* stated that US MLS ground station fielding would occur in two phases, with Phase I would procure about 464 stations through the year 2000, and Phase II would cover procurement of an additional 786 or more stations in the 1999 to 2008 time frame. Dual-source contractors were scheduled to be selected in March 1992 in a split 52-month development contract for delivery of six to twelve prototype Category II/III systems. The contract for the bulk of the Phase I requirement was to be awarded in April 1995. The interim requirement for Category I stations saw the award of a contract for two stations each to Wilcox and Bendix, with an option for 24 more. The DoD's planned procurement remained at 405 fixed-base stations.

In June 1992, the FAA announced that it had awarded two contracts totaling US$148 million, including options, for the design and development of advanced versions of the MLS. A contract for US$78.2 million was awarded to the Wilcox Corp of Kansas City, Missouri, and a US$69.8 million contract was awarded to Raytheon Corp of Marlboro, Massachusetts. Under the contracts, each company was to produce six test systems apiece. The first systems were scheduled for delivery in 1996. The new systems would be designed to enable aircraft to land in lower visibility conditions than existing MLS units. Both Wilcox and Raytheon were to independently design and build systems for two types of inclement-weather conditions: one for ceilings of 100 feet and visibility of 1,200 feet; the other for ceilings of less than 100 feet and down to 700 feet of visibility.

Category I MLS FAA sites are currently in operation at Wichita, Kansas; Kennedy International Airport, New York City, New York; and Midway Airport, Chicago, Illinois. Additionally, there are three privately owned sites that are FAA-certified: Hailey, Idaho, operated by Horizon; Valdez, Alaska, a city operation being taken over by the FAA; and Galbraith Lake, Alaska, which is near an oil pipeline pumping station. A fourth site, operated by the Department of Defense is located in Shemya, Alaska. Many of the MLS selected sites were in Alaska, northwestern US, and various mountainous regions across America. The 26 Category I stations delivered by Wilcox are for the demonstration phase.

The first Category II and III MLSs were scheduled to be operational in 1997. The FAA planned to install the first article systems developed by Wilcox and Raytheon. However, the FAA delayed a production decision for two reasons. First, the FAA planned to conduct independent operational testing and evaluation on the development of systems before awarding the full production contract. Second, since the agency is doing research to develop a satellite-based navigation system to be used for precision landings, the FAA planned to delay the decision to advance full production of Category II and III MLS until it determined the feasibility of using satellite navigation for precision landings.

The FAA expected to make this feasibility decision in 1995, at roughly the same time development of 12 Category II and III MLSs was to be complete. At the end of the development period, the FAA planned to award production contracts for the remaining 1,226 Category II and III MLSs to the contractors that are developing MLS. These systems would be installed at all current ILS locations. About 160 systems were planned for installation on international runway ends by January 1, 1998, for the FAA to meet its international commitment for MLS.

By the year 2000, the FAA planned to procure 464 Category II and III systems, including those that were under development (Phase 1), and to procure the remaining 786 MLSs after 1999 (Phase 2). The FAA planned to have all 1,250 systems procured by 2008. This was later modified to procuring 255 Cat II/III MLSs through 2000, and a final amount to be determined after studies were completed.

All of these plans came crashing down in 1994 when the FAA terminated its MLS efforts. Instead the agency turned to upgrading existing ILS systems to overcome reliability problems, reduce maintenance costs, and improve performance. Plans were to establish new Category I/II/III ILS upgrade plans and replace older Category I/II/III and Mark 1A systems; as well as starting a service life extension program for Mark 1B and 1C systems. Changeover would be done without removing the ILS capability at any sites where the system was operational.

Canada's MLS Program. Canada also has a large-scale MLS implementation in mind. In August 1989 it was announced that the government agency Transport Canada was planning to acquire 40 MLS ground stations from Micronav (with price and schedule to be negotiated). Forty-two stations were to be acquired in this first phase effort, with the additional two stations would be used for training and testing. The deployment schedule called for the first unit to be delivered in 1992, with the last to be delivered in 1994. The total procurement called for 145 units to be installed at more than 80 airports over the breadth of Canada during a 12-year period. In an approach comparable to that chosen by the US, the first phase would serve as a demonstration to persuade the

Canadian aviation community to support the use of MLS as the primary landing aid in Canada.

In April 1993, the Canadian Government took a bounding leap past the US on MLS installations, announcing an additional US$100 million for an additional 103 MLS installations. At that time, it was further announced that Micronav was awarded an initial US$14 million contract for 11 Category I MLS ground stations. Micronav has also been selected to develop Cat II/III systems under Phase 1 of the MLS program.

US Military Programs. The Army, designated lead service for JTMLS in FY76, blew hot and cold on the program, out of phase with a cold and hot Congress. By FY80, a US$5.9 million contract was awarded to Bendix (winner over Hazeltine/E-Systems/Singer and Eaton/ Gould/American Electronic Labs teams) for JTMLS advanced development models — military versions of the TRSB MLS with transportable, easily erected antenna systems. But the Army later canceled the program. The Army fielded an experimental microwave scanning beam landing system for helicopters called A-SCAN or PACSCAN, TRQ-36. The Eaton/AIL system was battery-powered and portable by one person; setup time is claimed to be five minutes; localizer, glide slope and DME were provided. However, there seems to have been minimal activity performed in this program. Telephonics later took over the TRQ-36 program.

The Navy has a specialized need for carrier landing systems. C-SCAN (Carrier System for Controlled Approach of Naval Aircraft), a FLARESCAN descendant, is a microwave scanning beam landing system from Eaton/AIL (later acquired by Telephonics). The shipboard transmitter is the SPN-41. The TRN-28 is a truck-transportable version for shore installations without the stabilization subsystem; and the ARA-63 is the airborne receiver. FLOLS (Fresnel Lens Optical Landing System) and DFOLS (Depth of Flash Optical Landing System) are visual systems — rather like VASIs (Visual Approach Slope Indicator) with sea legs. Bell/Textron's SPN-42 ACLS (Automatic Carrier Landing System) is a digital, solid-state version of the SPN-10; an SPN-46 ACLS has been developed under the Navy's Air Control Engineering PE#64504 as Project XO993, Carrier Air Traffic Control.

The SPN-42 ACLS combines mechanically scanned precision radar with gyro-stabilized ship motion compensation, computers, and data links to provide fully automatic landing capability. In practice, C-SCAN is used to vector aircraft to an acquisition window, for transition either to FLOLS or ACLS for landing; C-SCAN serves as a monitor and backup system from that point. Taken together C-SCAN, FLOLS, ACLS, NTDS (Naval Tactical Data System) computers, and data links comprise AWCLS, the All Weather Carrier Landing System – a versatile package for manual, talk-down, or automatic landings in either visual or instrument conditions. The Navy's plan for MLS has been to keep what it has and develop a multimode receiver that adds MLS capability to ILS, ACLS, and MRAALS (Marine Remote Area Approach and Landing System).

The Marines also are involved through the MRAALS which focuses on a microwave scanning beam landing system developed by Singer Electronic Systems (now GEC-Marconi Electronic Systems). MRAALS includes a portable (115-pound, 10-minute setup) ground subsystem, TPN-30 and a TACAN-compatible airborne subsystem, the ARN-128. (The ARN-128 was superseded by the ARN-138 multimode receiver, a program which has now, however, been placed on indefinite hold.) The Marines share the Navy's interest in a multimode receiver, especially since the Marines fly F/A-18s from aircraft carriers. However, in early 1990 the Marines tested MEL's MADGE at Yuma, Arizona. Trials were conducted with UH-1 and CH-53 helicopters. MADGE is being considered as a replacement for the existing precision approach radar. The MATCALS (Marine Air Traffic Control and Landing System), fielded by the Marines for all-weather operations at expeditionary airfields, was designed to be compatible with the MLS.

The US Air Force is involved in a 20-year program to convert from the use of PAR and ILS to MLS for all tactical and fixed-base precision landing systems. The USAF program has four clearly developed objectives: to provide interoperability with civil landing systems; to remove the military limitations of PAR such as its limited mobility, vulnerability, high manpower cost, and site sensitivity; to provide precision approach capability to austere airstrips; and to assure continued landing system interoperability with NATO (which had agreed to transition to MLS).

According to Air Force planning, by the year 2000, all Air Force bases and aircraft were to be equipped with MLS ground equipment and receivers. Acquisition of both ground equipment and avionics was to be paced to match civil aviation sector plans. Most acquisition costs were anticipated between 1990 and 1998. The first USAF MLS installation is at Shemya AFB in the Aleutian Islands.

The Tactical MLS ground station was intended as an all-weather precision landing aid that could be deployed in Grenada-like operations by a Military Airlift Command (MAC) combat control team. It was also to be used as a transportable backup for fixed-base MLS installations that have malfunctioned or been rendered inoperable by damage.

The US Army also has some requirements for such equipment. However, in FY86, Congress terminated the TMLS program on the grounds that TMLS did not take full advantage of the FAA's MLS efforts. The TMLS has been restructured from a 500-pound, air-droppable, man-portable system to a mobile system which is highly transportable, modular and weighs a maximum of 1,000 pounds. The TMLS became the MMLS (Mobile MLS) and part of a three-part USAF MLS program consisting of MMLS, FBMLS (Fixed Base MLS) and MMLSA (Military MLS Avionics). The MMLS specifically replaces the mobile precision approach radar which is in use at the present time for combat restoration and emergency mission support. The MMLS also gives Military Airlift Command Combat Control teams a new capability to execute special operations missions at austere airstrips/ landing zones.

A contract for the MMLS was awarded to Bell Aerspace in August 1988. The basic contract of US$46.1 million was for the design, development, and fabrication of six MMLSs. First flight tests were in the summer of 1990 at the Buffalo, New York, airport. Up to 132 systems were to be procured. USAF budget documents called for a start of production for 33 systems in the first procurement option in FY91. Sixty MMLSs were scheduled to be completed by FY94.

The acquisition was parallel to the FAA's second phase of procurement of fixed-base ground equipment. However, the cancellation of Hazeltine's Phase I contract for the regular ground station caused Phase II dislocations.

The original MMLS notice specified that the MMLS be an assembly of small, man-transportable, easily sited, and readily relocatable modules that carry out functions such as distance measuring, angle-guidance, azimuth/elevation, control and display, data transmission, and system support. The equipment had to be of two configurations, namely split-site and collocated. The former comprises a full complement of equipment, while the latter has a reduced complement to enhance deployability. The equipment provides a Category II capability, an operational time of more than two hours when operating from a battery power supply, and include a precision DME.

Bases in Europe and Korea were to be equipped with hardened/sheltered versions of the tactical, mobile system and incorporated into the Rapidly Deployable Air Traffic Control System, where the MMLS would work with the New Mobile RAPCON (possibly based on the MATCALS system). These systems would need the capability to vary the location of the elevation antenna to allow operation from surviving segments of damaged runways. The United States committed to NATO to equip main operating bases for MLS service by 1998. MLS is the designated replacement for the precision approach radars in NATO.

Alternatives to MLS. Although the advantages of MLS are not to be denied, many of the major airlines have been more than willing to wait on the purchase of MLS receivers until MLS service was actually in operation at several major airports. This would allow them to equip new aircraft with MLS as the aircraft come into service, limiting the cost of retrofitting existing aircraft. These cost concerns renewed serious talks on the advances made in ILS, FMS (flight management systems), and GPS – would they be feasible MLS replacements?

ILS technology has been constantly improving, and with the schedule for MLS production hitting snags, there was a possibility that more than one precision approach system would be used to satisfy the wide range of aviation making use of these systems. Several comparative studies were conducted comparing ILS and MLS with MLS's Category III capabilities, giving MLS an edge over ILS even though Category III weather is typically experienced less than one percent of the time at an airport.

The two systems are also competing in an increased demand for radio frequencies. According to the FAA's spectrum engineering department, the area between 5000 MHz and 5250 MHz has been reserved for MLS for over 15 years and many communication companies with an immediate need for frequencies are protesting these open slots being held for precision landing systems. Rockwell's Collins Avionics division has come up with an interesting solution in the form of ILS and VOR avionics that are immune to VHF FM broadcast interference, an increasingly pressing concern even in the US due to the proposed 1998 increase in the broadcast power of commercial FM radio stations. Collins offers both a new series of avionics and retrofits for existing models.

FMS is also gaining attention and is now being used experimentally by some US airlines to guide planes into final approach and then combined with an integrated GPS system that uses computer imaging to land in bad weather. However, this concept has been met with scorn by the FAA who believe such a synthetic vision system would be more expensive than MLS and actually represent a giant step backward for aviation as such a system must be used with manual landings. Most Category III approaches are done on autoland through a computer which is safer to use in bad weather than a human pilot flying manually and must contend with several bad conditions and make many decisions in but a few seconds.

Another system under consideration is a head-up display/ enhanced visual system (HUD\EVS). This system has been described as a cost-effective alternative to MLS receivers because it would provide input to the entire autoland system, not just the precision approach landing. The HUD/EVS would allow manual landing during bad conditions that normally call for autoland. Claimed benefits include: the requirement for only a Category I ILS or in some cases no ground equipment, increased information on adverse weather take-offs not available from autoland systems, and an overall lower maintenance cost compared to an autoland system.

GPS Wins Out In recent years a major threat to MLS developed in the form of a GPS (Global Positioning System)-based satellite navigation system. An integrated GPS that handles precision approach landings as well as navigation would be most welcome by air carriers who would not only get two outstanding systems, but also save a lot of money with a two-for-one retrofit. Under the present GPS system, significant technology enhancements need to be developed and engineered in order to achieve precision approach landings using satellites. A study of this possibility was completed in July 1990 and concluded that at the time, even including the Russian GLONASS system, the configurations were not available to meet Category II and III requirements for vertical accuracy, adding that to even make GPS precision approach landings possible would require major development.

A possible solution was the merger of MLS and GPS into one system. This was the thinking of the Mayflower Communications Co and Bendix Communications Division when they formed a joint venture in 1990 to develop a combination MLS/GPS system to increase the safety margin of pilots flying curved approached landings. Their design concept is based upon the theory that it is possible to lose MLS at some time during a curved approach if the plane, for some reason, masks the signal. By using GPS and the approach paths stored in an onboard flight computer, this combination MLS/GPS unit would allow the pilot to continue the approach until the proper MLS signal is restored or abort the approach and fly a safe departure route.

In theory, the plane would fly en route using GPS and an area navigation computer (RNAV) to navigate and then switch to MLS for a precision approach landing. Under this design, GPS was not intended to replace MLS and, therefore, did not have to be enhanced for precision approach landings; instead, it would be used as a temporary fail-safe to either continue the landing or abort safely during an MLS blackout. The actual equipment would consist of a control and display unit with combined MLS/GPS receivers and a RMAV computer. The TAU Corp was awarded a US$2.9 million dollar contract by the DoT to be the prime contractor in developing and managing this combination unit. Mayflower Communications was responsible for the GPS and RNAV, and Bendix was working on the MLS part.

By 1994 it was evident that a GPS-based satellite navigation system had become the most favored solution not only as a next-generation landing aid system, but also as a complete navigation system. A critical point was reached when the FAA declared in June 1994 that it was halting development of the Cat II/III MLS in favor of a GPS-based solution due to the latter's greater potential to provide precision approach landings, especially in view of the speed with which satellite technology is developing. The FAA canceled the contracts it had awarded to Raytheon and Wilcox for MLS development. And at its April 1995 COM-OPS meeting in Montreal, ICAO announced that it would drop its former mandate on MLS implementation by international airports by January 1, 1998.

GPS is already capable of providing Cat I capabilities, and work is progressing rapidly on GPS augmentation techniques that would allow Cat II and even III approaches/landings.

The USAF has its own landing system program, ATCALS. It is treated in detail in a separate ATCALS report.

Funding

The FAA is no longer funding MLS development. Service MLS ground station funding no longer is broken out.

Recent Contracts

Contractor	**Award ($ millions)**	**Date/Description**
GEC-Marconi	6.1	June 1993 — FPIF for EMD II of the MLSA, also includes option for antennas and three, one-year production options for up to a total of 2,200 systems (F19628-93-C-0116).
Textron	19.9	July 1993 — FVI to contract for 37 mobile MLS. Completion date: July 1995

(F19628-88-C-0062, P00030).

Timetable

	1967	RTCA Special Committee 117 (SC-117) formed to develop ways to overcome limitations of ILS
	FY71	National plan issued for development of MLS based on SC-117
	FY72	Technical proposals received from nine teams Phase I contracts awarded to six teams
	FY73	Phase II contracts awarded to four teams
	FY75	Phase III contracts awarded to two teams
	FY76	DoD designated Army as lead service for JTMLS program
	FY78	ICAO selected US/Australian TRSB System as international standard Joint FAA/NASA development of Basic Wide System began
	FY79	Development of Cat III upgrades for Basic Wide System began DME/P Subsystem development began
Nov	1982	Bendix MLS approved for service at Valdez, AK
Aug	1983	Bendix won MLS contract for USAF installation at Shemya AFB, AK
Apr	1984	First unrestricted operational MLS at Cadillac, MI
Aug	1984	Hazeltine won US$90 million FAA MLS Phase I contract
	FY85	USAF Systems Command/ESD designated to manage DoD TMLS program
Jan	1986	AOPA issued statement calling into doubt the efficacy of MLS for use in general aviation aircraft
Sep	1986	Canadian Marconi held first combined test of its airborne MLS receiver against its MLS ground station
Aug	1988	Bell Aerospace awarded design, development, and fabrication contract for TPN-45 MMLS
Aug	1989	FAA canceled Hazeltine MLS contract
	FY91	MMLS production decision
Jul	1991	Bendix awarded contract for two Category I off-the-shelf stations
Jun	1994	FAA announces cancellation of Cat II/III ground station development
Mid	1995	ICAO drops mandatory MLS requirement

Jan	1998	Official date by which MLS was to become international standard – rescinded by ICAO in April 1995
	2010	Earliest date by which ILS must be replaced by new precision landing system (no system yet endorsed by ICAO)

Worldwide Distribution

The following is a comprehensive listing of existing or planned installations of MLS ground stations throughout the world. One should keep in mind that these numbers are very likely to be reduced substantially, in view of the fact that MLS has been dropped as the mandatory worldwide precision landing system:

Australia. The Australians planned to equip all ILS-equipped runways with MLS by 1998. There was the potential market for about 20 MLS systems. An Interscan ground station was installed in early 1990 at Canberra Airport for the validation of the design, maintenance and calibration techniques of the company's system. The project's cost is about AUS$2 million. Interscan estimated the regional demand to be between 40 and 50 stations, which probably includes New Zealand as well as various island nations in the general area.

Austria. Austria planned to equip nine runways at six airports with MLS stations.

Belgium. The Belgians have planned to equip MLS stations at total of nine runways at five airports.

Brazil. The Brazilians have stated that they would be fielding MLS equipment at 10 international airports by 1995. A further 75 airports would also receive MLS stations subsequent to the equipping of the international airports. Of the former, 61 of them were not currently equipped with ILS. A total of 87 ground stations are projected.

Canada. Canada has been at the forefront of MLS station installation, with systems in service at Jasper-Hinton and Lloydminster airports in Alberta, Uplands Airport in Ottawa, Port Hawkesbury in Nova Scotia, Pemberton in British Columbia, two in Alberta, and one at Toronto Island Airport (two Micronav ground stations). CMC currently has an MLS ground test range at Kanata, Ontario.

The original fielding plan, as cited in the 1986 edition of the Canadian Airspace Systems Plan, called for the installation of MLS ground stations in parallel with the existing system between 1989 and 1998, with airports requiring new precision approach equipment to receive MLS rather the ILS after 1989. According to the fielding plan, 41 Phase I ground stations were to be fielded between 1987 and 1991, and 113 Phase II ground stations were to be fielded between 1991 and 2000. A total of 162 ground stations were projected. However, this plan was superseded and fielding delayed. A revised plan issued in late 1989 called for Micronav to supply 42 systems: 40 for installation at various airports, and two for training and testing. The 40 regular ground stations began deployment in 1992, with the last system scheduled to be installed in 1994. This was the first phase of a 12-year effort to install a total of 145 ground stations at over 80 airports across Canada. The first phase effort is also critical in that it should prove the viability of using the MLS system.

The Canadian government made a real leap of faith in MLS in April 1993 when it announced an additional US$100 million for an additional 103 MLS installations. At that time, it was further announced that Micronav was awarded an initial US$14 million contract for 11 Category I MLS ground stations.

China. In mid-1991, the Chinese government, through the Xian Research Institute for Navigation Technology, signed a partnership agreement with Interscan of Australia for the possible provision of MLS stations at up to 150 airports throughout China. The preliminary order was for three Category III stations. The Chinese have indicated they would standardize on Interscan technology, although there is likely to be licensed-production in China after some point.

Denmark. The Danes planned to install MLS stations on a total of 25 runways at 12 airports. Implementation was originally scheduled to begin in late 1989, but was delayed one year until late 1990/early 1991. The reason for the postponement was that Denmark, like many countries, especially the smaller ones, wanted to review the cost-effectiveness of MLS in comparison to the many alternatives being bandied about.

Germany. Germany planned to install about 20 stations by the year 2000. An SEL MLS ground station was ordered for the Frankfurt airport in 1990, after initial trials at Braunschweig airport. This is the first fully operational MLS system in Germany. Almost all of the installations are slated for the western zone. There has been little information regarding upgrades to any of the facilities in the former East Germany, which no doubt require substantial investment.

France. In 1990, France started an MLS evaluation using Thomson-CSF equipment at Charles De Gaulle International Airport, to be later joined by an evaluation at Toulouse. France has planned to install a total of 49 ground stations by 2000.

Greece. Greece has planned to install MLS stations on four runways at four airports.

Italy. Italy's intention was to install MLS stations on 28 runways at 25 airports. An installation at Rome Airport has been used for evaluation purposes.

Japan. The Japanese installed an MLS ground station at Sendai Airport (near Tokyo). The system was manufactured by NEC (with help from Toshiba). NEC signed a cooperative agreement with Hazeltine regarding MLS codevelopment and coproduction. The Japanese have projected a requirement of 50 ground stations.

The Netherlands. The Dutch planned to install MLS stations on eight runways at five airports. They are cooperating with the British and their MLS evaluations at Heathrow Airport. The first Dutch MLS installation, a Canadian Marconi Model 2500 Widescan MLS, was installed at Schipol Airport.

Norway. The Norwegian Telecommunications Administration procured a Type 840 MLS from Thomson-CSF for installation at the Oslo-Gardermoen airport. In September 1988 an order was placed for a Hazeltine Model 2601A for installation at Oslo Airport. The country plans to install 52 ground stations at 40 airports.

Spain. Spain scheduled installation of 27 ground stations at 22 airports by the year 2000. The first station (Category III) was installed at Salamanca in mid-1991 in a joint project between Interscan and ENA Telecomunicaciones of Madrid.

Sweden. By the year 2000, Sweden's intention is to have 45 ground stations at 37 airports installed and operating.

Russia. The Russians originally developed an MLS system of their own named *Vipere*. The *Vipere* system was equipped with six DME/Ps for use at Baikonur Space Center to land the since-mothballed Buran space shuttle flights. *Vipere* was successfully tested with an unmanned version of the Buran. Planners were to initially install MLS stations at about 20 airports. Since the then-USSR did not have a well-established ILS system, it wanted to develop an advanced ATC system based on the MLS. The world's first Category III MLS was installed at Moscow's Sheremetyevo Airport. St. Petersburg (formerly Leningrad) Airport was also scheduled for evaluation trials. However, with the breakup of the Soviet Union, whatever plans there were seemed to have gone into limbo or were completely canceled. The need is still there for more advanced precision landing systems, funding for any MLS procurement at this time is rather doubtful. They are teaming with the West on a variety of ATC upgrades, though. The Russians are now well positioned for GPS use, its 24-satellite GLONASS system now in place and operational.

Switzerland. The Swiss planned to install six ground stations at four airports.

United Kingdom. A Plessey P-SCAN MLS ground station was permanently installed at Heathrow Airport in London (Category III runway) for site test. This facility was not meant only for UK trials, but was also to involve the FAA, the Netherlands Department of Civil Aviation, and the German Bundesanstalt fur Flugsicherung. Another Plessey MLS ground station was installed at Cardiff Airport as the first UK regional trials site for CAA (Civilian Aviation Authority) testing of MLS technology. The latter ground station has also been situated at the Royal Aerospace Establishment at Bedford, and Manchester, Gatwick, and Dunsfold airports. A Siemens-Plessey P-SCAN 2000 Category III station was installed at Heathrow in 1993. A Textron MMLS was installed at London City Airport in early 1994 for testing steep approach capabilities, as well as the ability to deal with the high incidence of ILS multipathing caused by the concentration of high buildings in the area. The CAA had already tested the same MMLS at the Cardiff-Wales Airport, another facility where ILS signal degradation by local structures is a problem.

MEL (under license to Hazeltine) installed an MLS at Yoevil, Somerset (for use by Westland helicopters), which was the first MLS installed in Europe, although it is intended for research purposes. The first installation of MLS in England for service trials was at Aberdeen Airport, the world's busiest heliport. The UK has planned to install 43 MLS ground stations at 23 commercial airports. The military requirement was for 90 MLS transmitters, including mobile training units. MLS ground stations are to be installed at 48 MoD air bases. The British have planned to replace NATO precision approach radars (PARs) with MLS.

United States. Since 1984, the FAA has acquired 30 Category I MLSs. The latter 26 systems began delivery in June 1993, a delay of one year. By June 1994, 24 had been delivered, with the remainder scheduled to complete delivery by the end of 1994. The systems were to be used for testing, developing approach procedures, and operational purposes.

The FAA does not plan to procure any more Category I MLSs at this time. Development of the Category II and III MLS ground stations was canceled in 1994.

Forecast Rationale

The ill-starred MLS program was dealt a serious blow with the June 1994 FAA decision to scrap development of the Category II and III MLS in order to pursue the GPS alternative. The decision was not unexpected, although the FAA's early and firm commitment to GPS did cause some surprise. The death knell for MLS sounded at a meeting of the International Civil Aviation Organization (ICAO) in March 1995, where it was officially announced that ICAO had dropped its mandate on MLS implementation by airports worldwide by the year 1998. Instead, they can be installed just where needed. A decision has yet to be made on what next-generation precision landing approach system would be adopted worldwide. ICAO has issued a nonbinding statement recommending that a five-year warning be given prior to decommissioning existing landing systems.

While momentum has shifted to a GPS-based approach, there remains some significant support for MLS, especially in the UK. Because of the need for further development of GPS to provide the minima needed for Cat II and III approaches, proponents of MLS argue that MLS is still viable, particularly in Europe where Cat II and III approaches are much more common than in the US, and where ILS signals face an increasingly saturated radio spectrum. There is considerable sentiment in favor of a multi-system approach, where the avionics would be dual MLS/ILS or MLS/GPS or some combination thereof, providing a redundant capability as a fail-safe measure. The main source of unease with the worldwide use of GPS stemmed from the fact that the US Department of Defense controls the satellites, thus creating uncertainty over availability in a time of war. The release of the ability to use the more accurate GPS modes to non-military users relieved some of the stress.

On the whole, though, there is doubt about the future for MLS. The momentum has swung overwhelmingly in favor of GPS, and MLS's checkered history of delays further works against its implementation. If MLS had been fielded according to original scheduling, its story might have ended differently. But considering the program's poor progress record, the common feeling now is that it is time to commit to a true next-generation system.

In favor of GPS is the fact that its implementation is likely to be a lot less problematical, and thus speedier. There will be some delay, with 2005 being the likely end of the transition period. However, improvements in ILS technology, especially in the rejection of FM interference, mean that ILS should be of capable of handling the interim landing/approach requirements (at least the majority of them). Because of the move toward GPS technology, we have reduced our MLS forecast to a bare minimum. Emphasis is on possible applications in areas of the world where local conditions necessitate some special equipment, such as in mountainous regions, or where satellite coverage may not be as complete as desirable. MLS would also be needed in some UK and Scandinavian countries, whose older ILS systems are expected to become degraded and will need to be replaced before GPS is able to provide Cat II or III precision landings.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level			Good Confidence Level			Speculative			
Designation	Application	thru 96	97	98	99	00	01	02	03	04	05	06	Total 97-06
MLS GROUND STATIONS	VARIOUS	155	30	30	25	15	0	0	0	0	0	0	100