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AN OVERVIEW OF FAA ACTIVITIES
IN
CIVIL AVIATION METRICATION

ADVO 038413

Carlo Yulo

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16. Abstract <p>An overview of FAA involvement in civil aviation metrication activities is presented. The problems associated with conversion of the National Airspace System are summarized. A system analysis effort is proposed to obtain a better understanding of metric conversion impact and to forecast risk factor(s) in order not to compromise safety. An engineering and development program is outlined to serve as a stimulant to initiate or provoke further thinking in describing what needs to be done.</p>			
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INTRODUCTION

The Metric Conversion Act of 1975 (PL 94-168) declares that the policy of the United States (U. S.) shall be to coordinate and plan the increasing use of the metric system in the United States. It also establishes a 17-member United States Metric Board to devise and carry out a broad program of planning, coordination, and public education, consistent with other national policy and interests with the aim of implementing the voluntary conversion to the metric system. When President Ford signed this bill, he did so "with the conviction that it will enable our country to adopt increasing use of this convenient measurement language both at home and in our schools and factories and overseas with our trading partners." He also said "The truth is that our continued use of the english system of measurements was making us an island in the metric sea." The metric system of measurement was defined by the public law to mean the International System of Units (SI) - Le Système International d'Unites. SI is the modern version of the classical metric (MKSA - meter, kilogram, second, ampere) system being adopted throughout the world. (Reference 1).

The passage of this act has caused an increased tempo in metrication activities in both government and industry. Seventeen individuals had been nominated by former President Ford to serve on the United States Metric Board. President Carter is reviewing the selection. The time is not too distant before this board will be established, and this no doubt will add impetus to metrication activities.

In 1972, the American National Standards Institute (ANSI) recognized the need for national coordination of metric conversion activities, and recommended that a coordinating mechanism be established within the private sector. This recommendation was strongly endorsed at a meeting of industry, business, and government leaders; and in December 1972 the ANSI Board of Directors approved the formation of the American National Metric Council (ANMC). Prominent individuals representing major industries, small business, organized labor, consumers, and education accepted the invitation to serve on the ANMC Board of Directors. The Board held its first meeting on May 7, 1973, and the Metric Council was underway. It was recognized that when national metric conversion legislation was passed, a national metric conversion board (government-sponsored) would be established. It was assumed that ANMC would maintain close liaison with and facilitate the work of the government metric conversion board by providing an established working interface with the private sector.

ANMC is a nonadvocate organization. ANMC operates under the principle of voluntary consensus of consumer, labor, professional, technical, and trade organizations. By addressing the situation with a business perspective, the ANMC mission is to ensure that metric conversion in the private sector is done in an efficient and timely manner.

Within the ANMC an Aerospace Sector Committee (ASC) has been organized to serve as a focal point for aerospace metrication. The basic objectives of this committee are to establish a cost-effective coordination mechanism; identify metric-sensitive legislation and regulations; coordinate industry's effort with appropriate government organizations; coordinate development of metric standards and specifications; and serve as a source of metrication communication for aerospace. They held their first meeting in November 1975. The Federal Aviation Administration (FAA) has representatives serving on the committee and subsector committees.

BACKGROUND

In 1968, Public Law 90-472 was enacted and authorized the Secretary of Commerce to make a study to determine the advantages and disadvantages of increased use of the metric system in the U. S. FAA was represented on the committee formed to perform the study. The results of the study are incorporated in the report, "A Metric America - A Decision Whose Time Has Come," which was sent to Congress in 1971. (Reference 2). The study revealed that the majority of those queried agreed concerted action should be taken to bring about metric conversion in measurement units and engineering standards. It was also realized, however, that there are practical problems of conversion in the case of air navigation, because of the established use of feet for altitude, elevation, and height; feet-per-minute for vertical speed; and nautical miles. (It should be noted that in the aviation community the metric system of measurement is an island in the english sea.)

In the 1971 National Aviation System Policy Summary (Reference 3), the FAA identified the problems associated with standardization of units of measurement as one of the major issues facing aviation in the 1970's. This policy summary also established that any program to be adopted by the FAA for use in aviation should be based on the International System of Units because of its worldwide applicability.

In 1974, the Secretary of Commerce expressed his belief to the Secretary of Transportation, as well as to the heads of other federal departments and agencies, that it was time to begin thinking seriously about the adaptations and adjustments that will need to be made as more and more of the nation's activities change to the metric system. In 1975, the Department of Transportation's (DOT) Assistant Secretary for System Development and Technology was assigned the technical lead for metric conversion in DOT and established the DOT Metrication Working Group. The FAA was a member of this group. In January 1976, the working group was disbanded when the DOT Metric Coordinating Committee was established. FAA has represented membership in the committee. This committee will act in a consulting capacity to the Secretary and other elements of the Department. The DOT Metric Coordination Committee has prepared a proposed DOT Order and formal departmental approval is scheduled for 1977. This order levies responsibilities on each operating administration to develop a phased plan of action for their orderly conversion from the customary system to the SI system consistent with operational, economical, technical, environmental, and safety considerations.

Summary of Problems

With the size of the U. S. air carrier fleet numbering about 2,700 aircraft, and some 168,000 active general aviation aircraft in the system, it is evident that conversion to the metric system will be extremely costly. (The following estimates of cost are conservative, and are to be used only for first order assessment and overview purposes. It is not intended to reflect the actual market cost since technology and production techniques are rapidly changing.) Among the aircraft instruments that will have to be replaced, it is conservatively estimated that for the air carrier fleet it will cost about \$4,000 to replace each encoding altimeter, about \$3,000 for each mach/airspeed indicator, and \$1,000 for each vertical speed indicator. For general aviation aircraft, the typical instrument cost is conservatively estimated at \$200. (It may be possible to change display dials which would cost considerably less.) These are the base costs of the instrument and if installation costs are added, the total cost could approximate upward of \$300 million, which is fairly significant just to handle the problems of changing three aircraft instruments. This does not cover military aircraft or other equipment such as vertical velocity and rate-of-climb indicators or flight data recorders which will also have to be converted. By 1988, the air carrier fleet will number around 3,500 aircraft and the general aviation fleet about 267,000; so one can see the monumental task that could lie ahead.

There is also the ground-based equipment that will have to be changed as a result of conversion to the metric system. This includes such equipment as cloud height measuring systems, radar, radar beacon, and DME systems. In addition, the air traffic control computer program will require extensive redesign of the algorithms and data tables used in these programs. These equipment conversions and the extensive testing that will be necessary to validate these conversions will require many man-years of effort, and the costs will be extensive.

Machines and equipment, of course, can be modified mechanically and electronically and programmed to do what they are told. But in the real world we must also consider the human/machine environment in which the aircraft pilots and air traffic controllers will have to relate and react to metric dimensions during critical split-second operation which requires human automotive reaction achieved through years of actual experience. With some 728,000 pilots and 324,000 non-pilots such as air traffic controllers, flight engineers, and mechanics involved, one can see the problem associated with human/machine relationship is one of aviation safety and one that requires the most severe scrutiny, far beyond cost. Thus, retraining programs would be required to ensure that flight and ground personnel are capable of functioning effectively in terms of the metric unit. Nevertheless, there will always remain in some cases and under certain conditions a finite risk that some personnel would inadvertently revert to the present system. However, these factors must be weighed against others such as (1) SI is coherent, hence many in-flight computations will be simpler and less error-prone, and (2) failure to convert may some day result in aviation training requiring learning of an alien more complex system of measurement.

Other problems that must be faced are the administrative burden of reprinting the various charts, manuals, and other publications including Federal Air Regulations and Advisory Circulars; the time that will be required for conversion; and the need or desirability of having a dual system for a given period of time.

These are just some of the many technical, operational, and economical problems that must be carefully examined and resolved to ascertain how to make the change without compromising safety.

FAA Consultative Planning Conference on Aviation Metrication

In keeping with FAA policy to hold various consultative planning meetings with the aviation community and the general public to obtain their input on key policy and planning matters affecting the National Aviation System, the FAA conducted a consultative planning conference on aviation metrication on November 16, 1976. (Reference 4). The purpose of the conference was to

interchange views and ideas on metrication with the aviation community and the general public that will help shape future plans and policies of the FAA with respect to metrication, specifically in those areas which FAA has statutory responsibility. This did not exclude discussions of aerospace considerations that may impact on the aviation community, but stayed away from any discussion of hardware as this should be worked out by the aerospace industry. The items of major interest were developed by an ad hoc government/user working group and were placed on the agenda. They were Air Traffic Control, Aircraft Operations, Airports, Weather Observing and Dissemination, Aeronautical Charts, Personnel Training, Navigational Aids, Design and Manufacture of Aviation Products, Maintenance in Support of Aviation Products and Transitioning. This ad hoc group was composed of representatives from the National Aeronautics and Space Administration, United States Air Force, General Aviation Manufacturers Association, Aircraft Owners and Pilots Association, Air Transport Association of America, and Aerospace Industries Association.

In summarizing the results of the planning conference, it became obvious that within the U. S. there is no specific government policy stating the U. S. will totally convert to metric within a given time frame. Therefore, any decisions in terms of metric planning or policymaking had to be made within that context. As a result of the absence of any overall government policy, certain fundamental issues had been raised at the conference regarding the movement of aerospace industry toward metrication. These issues were: the lack of incentives for change; the question of who takes the leadership; and question of risk in the air traffic control and navigation areas. It was pointed out that at present there are no perceived payoffs in moving toward metrication although this could change in time depending upon export markets and other factors.

In the absence of any federal policy and regarding who takes leadership responsibility, it was pointed out that industry is waiting for the FAA to take the lead in areas for which FAA has no statutory responsibility. However, the FAA is looking for some signs that the aviation community is desirous of moving metrication. Consequently, nobody is proceeding very rapidly. The last issue was the question of risk and this is a serious question and is paramount in FAA's thinking. It was emphasized that if the agency believes any hard conversion would substantially increase the short-term risk or could perhaps precipitate accidents, the FAA would move very slowly and cautiously toward metrication.

Current FAA Activities

At the conference, the FAA reported on its ongoing and planned metrication activities. The attendees learned that although FAA has not implemented a specific plan and/or schedule for any changeover to metric units, the agency is assessing the impact

of metric conversion on air transportation and is actively looking at the many technical, operational, and economical problems that need to be carefully examined and resolved before the civil aviation community can convert to metric. A preliminary assessment performed by the Systems Research and Development Service was reported on to date. Their assessment, which was based upon the assumption that the operating characteristics and parameters of the National Airspace System, will be designed around SI units and resulted in the following findings:

1. Technical aspects of metrication are academic in that the engineers readily relate to metrics. While considerable effort will be needed to incorporate SI units into standards and specifications, the technical impact is regarded as minor.

2. Hardware modifications to obtain metric readouts in the air traffic environment would require prototype kits constructed to measure operational burdens. A first order determination of costs to develop modification kits (prototype) for a radar, an Air Traffic Control Radar Beacon, Distance Measuring Equipment (DME), and other equipment is estimated at \$750,000 and 10 workforce years over a 1-year period. Testing of these changes is estimated at \$200,000 over a 6-month period.

3. Metrication of software represents one of the largest development costs in the conversion process. NAS En Route Stage A, ARTS II automation, DABS/En Route Stage A, and DABS/ARTS III interfaces must be included. Extensive testing to validate the conversion is estimated at \$1.5 million and 30 workforce years over a 1-1½ year time frame.

4. The criticality of the human/machine interface requires an assessment of the safety implications engendered by veteran air traffic controllers and pilots. A human factors study will be needed to determine: (1) pilot and controller acceptance, (2) impacts on operational safety during approach and landing, (3) optimum display configurations, (4) impacts on air traffic control operation, (5) the impacts when pilots and air traffic controllers relate to metric dimensions during critical operations which require human reactions achieved through years of experience using the customary english system, and (6) develop training techniques to minimize the effects of (1), (2), (3), (4), and (5).

5. One other adjunct to the R&D cycle is the National Aviation Facilities Experimental Center (NAFEC) where the FAA tests and evaluates concepts and equipment. An initial assess-

ment for conversion of the NAFEC facilities and the various laboratory R&D aircraft has been conservatively estimated at 2.3 million dollars with 62 workforce years required over a 5-year period.

It was also reported that Air Traffic Service has carried out assessments of documentation revisions necessary for metric conversion--as well as the time required to achieve conversion. They concluded that up to 12 months leadtime will be necessary to convert handbooks, Federal Aviation Regulations, and Advisory Circulars promulgated by the Service. ATS now shows metric conversion tables on 6 of the 18 aeronautical charts they prepared, but there are no plans to convert the other aeronautical charts nor Instrument Approach Procedure Charts until there is a user demand for such conversion. They also represent the FAA on the Federal Metrication Working Group for Meteorological Services which is involved in an overall effort to develop recommendations for meteorological metrication, including aviation metrication within the Federal Government.

Reports were given on other FAA elements involved in metric planning and included the Office of Aviation System Plans (serving as a focal point for coordination of metric efforts), the Office of Airports Programs (which includes metric equivalents in some of its publications), the Airway Facilities Service (which is planning to provide for future use of metric units in engineering procurements), and the Office of International Aviation Affairs (which spearheads agency efforts in working with the International Civil Aviation Organization (ICAO) toward the achievement of the unification of units of measurement). Another major element, Flight Standards Service, is active and staying on top of development in aviation metrication. As a service organization, it reacts to the aviation industry and will follow the industry's lead in metric conversion. This Service is technically qualified to evaluate metric designs and metric engineering software submitted by the aviation industry. As a result of an assessment of agency metrication training needs carried out by the Office of Personnel and Training, the conference was advised of their preliminary findings that three levels of metric training will be required.

ANMC - Aerospace Sector Committee (ASC)

The ASC has held four meetings since its initial meeting in November 1975. There was FAA representation at each of these meetings. The ASC organizational structure has been defined, appropriate membership and liaison established, general objectives have been made, and short-term tasks initiated. The scope, tasks, and membership of the various sub-sectors

of the ASC have been definitized and provisions made for additional sub-sectors or special task groups as may be required. Thus far, four sub-sectors have been established of which three are technical and hardware oriented and they are proceeding satisfactorily and without any serious controversy. However, the fourth sub-sector, Aircraft Operations, has had serious differences of opinion between the sub-sector and the sector. This is further compounded by the non-attendance or participation by segments of the aviation user. The controversy centers around the premise that the operation sub-sector activities are premature and, also that its activities fall within the responsibility of FAA, and they (FAA) have established mechanism to conduct consultative planning with the users. It is noteworthy that the ANMC is deeply involved in the movement toward metrication in the U. S. and will probably be one of the key organizations used by the U. S. Metric Board to facilitate the implementation of their forthcoming metrication plan. However, the basic responsibility for the national airspace and flight operations rests, by law, with the FAA and any move toward metrication in these two areas will be FAA's responsibility. Nevertheless, there is a role for ASC similar to any interested group providing comments, ideas, and recommendations to the FAA for consideration.

ICAO - Standardization of Units of Measurement

On the international side, the ICAO Annex 5 (Reference 5) prescribes the units of measurement to be used in Air-Ground Communication. It should be noted that the ICAO tables differ from the SI system. Furthermore, member States have taken exception to the ICAO table. The 21st session of the ICAO Assembly resolved that the unification of units of measurements to be used in international civil aviation shall be achieved on the basis of the International Systems of Units (SI) except in those cases in which it appears impractical or undesirable to do so. In January of 1976 the Air Navigation Commission was unable to resolve this issue and requested the ICAO Secretariat to conduct a 1-year study to determine the impact of such a change to identify changes to existing procedures and equipment that would be necessary if the SI table were adopted.

In January 1977, the Secretariat completed its study and reported back to the Commission (ANWP/4627 dated 1/2/77). (Reference 6). It concluded that the current edition of Annex 5, by itself, is not sufficiently broad in scope to promote fully the ICAO objectives of a single standard system of units of measurement based on the International System of Units except in those cases where the use of a specific SI unit is impractical or undesirable. It also concluded that the

aviation industry has been slow to implement the SI primarily because of the lack of adequate financial incentives and lack of knowledge concerning the effects on safety. It further concluded that three basic sequential phases of planning are required to achieve the Organization's objectives. An initial phase which would consist of the revision of Annex 5 to encompass the use of SI units, with specified exceptions which reflect present realities. A later intermediate phase which would follow the initial phase and consist of the development of implementation plans for the exclusive use of SI units and those units outside the system which have been retained for general or temporary use. (This phase could require ten-to-fifteen years for completion.) A final phase consisting of the development of implementation plans for the exclusive use of SI units and those units which have been retained for general use in aviation, and that the intermediate and final phases of planning must take full account of financial incentives and human factors. (It is expected that full implementation could require an additional ten years.)

The Air Navigation Commission agreed with the findings and recommendations which were to agree in principle to the concept of a multi-phase process of implementation, request the Secretary to develop proposals for consideration by the Commission during its next session, for the amendment of Annex 5, and request the Secretary to report back to the Commission within one year's time with a study concerning the development of implementation plans for the later phases.

CONCLUSION

Metric conversion can no longer be taken lightly or with disregard; metric (SI) is here. FAA must be in a position, when called upon, to speak with authority to either support or dispute the merits of proposed metric changes.

The problems associated with metric conversion deserve attention. The timetable for metrication is most speculative and tends to contradict any incentive to act now on metric changes. However, this should not be the case as it is important to determine now what problems are associated with metrication and be prepared when the transition begins. A long lead time is necessary.

It is incumbent on FAA to initiate a detailed assessment program to determine the impact to the safety of operational changes to existing procedures and equipments. Consequently, FAA must shape future plans and policies with respect to metrication as they apply to its statutory responsibility.

RECOMMENDATION

It is recommended that an in-depth system analysis be conducted to determine the impact/risk involved in metric conversion. This effort should prescribe the course of action, investigations, studies, and technical activities required to effect an orderly transition. The end result should provide a better understanding of metric conversion impact, reduced risk, and in no way compromise safety.

The specific objectives of such an effort should be:

- o Conduct an in-depth system analysis to determine the impact/risks involved in metric conversion and the related safety aspects.
- o Conduct a criticality analysis of the human factor aspects of the human/machine interface.
- o Determine pilot, air traffic controllers, and technician acceptance.
 - o Determine impact on operational safety during approach and landing.
 - o Determine optimum display configuration and readability.
- o Conduct an analysis to determine the human, technical, operational, and economic impact as related to hard/soft (english measurement converted to equal metric measurement) and hybrid conversion (such as metric altimetry while retaining nautical mile).
- o Conduct studies and real time simulations on the above analysis to investigate the various aspects of the air traffic control system, rules, procedures, concepts, workload, and equipment.
- o Determine the effects of (1) time that conversion is started and (2) rate of or speed of conversion (i.e., all parameters at once vs. staged conversion).
- o Define and establish training programs for pilots, controllers, and technicians, etc.
- o Review published Federal Aviation Regulations and Advisory Circulars to preclude design limitations.

The overall effort should be given proper recognition at the program element level with associated subprograms. The following is an outline of proposed activities which are not necessarily all inclusive but can serve as the stimulant to

initiate or provoke further thinking in describing the work that needs to be done.

SUBPROGRAMS

System Analysis

- Operational Analysis
- Criticality Analysis
- Impact/Risk Analysis
- Separation Standard Impact Analysis
- Economical Analysis
- Hard/Soft Conversion Analysis
- Transition Analysis
- Hybrid (mix English/Metric) Conversion Analysis
- NAFEC Test Bed Design Analysis
- Published Federal Aviation Regulations Impact Analysis
- Published Advisory Circular Impact Analysis
- ICAO

Air Traffic Control Metrication

- Human/Machine Interface Study
- Real Time Simulation Activities
- Safety Impact Investigation
- Personnel Training Requirements
- Rules and Procedures Impact Study
- En Route Design Investigation
- Software/Hardware Design Investigation
- ATC Display Design Investigation
- Aeronautical Chart Design Investigation
- Hard/Soft Conversion Feasibility Investigation
- Hybrid Conversion Feasibility Investigation

Communication/Surveillance Metrication

- Software/Hardware Design Investigation
- Radar Techniques Investigation
- ATCRBS Mode C Design Investigation
- ATCRBS National Standards Impact Study

Navigation Metrication

- Base 10 Navigation System Analysis
- Base 10 vs. Base 12/60 Navigation System Comparison
- Human/Machine Interface Study
- Real Time Simulation Activities
- Safety Impact Investigation
- Personnel Training Requirements Study

En Route/Terminal Airway Width Investigation
Hybrid System Feasibility Investigation
VORTAC Extended Service Volume (ESV) Impact Study
VORTAC National Standard Impact Study

Airport Metrication

Airport Design Investigation
Air Traffic Surface Control Design Investigation
Airport Lighting Design Investigation
Airport Visual Aids Design Investigation
Landing Visual Aids Design Investigation
Airport Structural Design Investigation
Airport/Runway Marking Design Investigation
Hard/Soft Conversion Feasibility Investigation
Hybrid Conversion Feasibility Investigation

Aircraft Metrication

Aircraft Safety Analysis
Flight Operation Analysis
Flight Control Design Investigation
Cockpit Instrumentation Design Investigation
Structural Design Analysis
Impact/Risk Analysis
Hard/Soft Conversion Feasibility Investigation
Simulation/Training Requirement Study
Certification Impact Study
Federal Air Regulation Impact Study
Advisory Circulars Impact Study

System Integration/Implementation

System Engineering Study
System Interface Study
Implementation Requirements Study
Reliability/Maintenance Impact Study

Approach and Landing Metrication

Human/Machine Interface Study
Real Time Simulation Activities
Safety Impact Investigation
Procedures Impact Investigation
Personnel Training Requirement Study
Cockpit Display Design Investigation
Instrumentation Design Investigation
Approach Plates Design Investigation
Hard/Soft Conversion Feasibility Investigation
Hybrid System Feasibility Investigation
Base 10 vs. Base 12/60 Navigation System Comparison Study

Flight Information Service Metrication

Human/Machine Interface Study
Real Time Simulation Activities
Display Design Investigation
Software/Hardware Design Investigation
Personnel Training Requirements Study
Weather Observation Investigation
Weather Dissemination Investigation

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