Advanced Satellite Systems for Post 2010 Aircraft Traffic Control and Monitoring Capabilities: Design and Spectrum Challenges

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It is now possible to design and implement new broadband satellite telecommunications and space navigation systems that could greatly enhance air safety, airline security and air traffic management and control. Such a new system would be very challenging in that it implies significant new broadband mobile satellite communications capabilities in terms of throughput, reliability, beam interconnection, processing and switching and two-way and multi-point interconnection with an ever increasing fleet of aircraft. Such a system might indeed require new frequency allocations for this purpose. The first critical step that is needed is to conduct an in-depth feasibility study that would scope out the expanded range of information needed to implement such an expanded and modernized system.

Key elements of this process would be to:

a. Identify and prioritize the aviation subsystems and components that could be monitored for wear-out, stress failure, or potential sabotage that should be included in a next generation of aircraft safety and fault detection system and to specify in detail the performance and reliability of the associated detection devices and sensors, aircraft monitoring systems, and aircraft.
b. Identify and prioritize the characteristics the elements in a new aircraft traffic monitoring system and the associated video and data recording equipment and associated volume of IT information, beyond the 66 data elements now recorded in the cockpit data recorder or the flight data recorders, that would be associated with a next generation aircraft traffic monitoring system.
c. Identifying and prioritizing proposed enhancements to the aircraft traffic control system that would be associated with a new space based system that would allow closer and denser aircraft spacing (from 10 to 50 times closer spacing) more fuel and operations efficient aircraft routing, while ensuring that international standards for airline safety (namely 1 accident per 3 billion passenger miles flown) would be met or perhaps exceeded.
d. Identifying and prioritizing the most promising new satellite technology and systems, design the most cost efficient and aerodynamically smooth aircraft mounted antenna systems, identify any needed GPS equipment augmentations and identify the associated air and terrestrially based computer systems that need to be installed and then integrated to create a seamless advanced space-based aircraft monitoring and traffic control system.
e. This effort would then need to be subject to detailed systems engineering and optimization in order to develop a system that would be cost effective, improve safety monitoring, improve real-time traffic monitoring, reduce fuel costs and consumption, allow for real-time capture of aircraft traffic monitoring information and enhance aircraft traffic control in terms of safety, automation, and efficiency of international operations.

Such a system, once designed and implemented should indeed be able to greatly enhance longer-term airline safety, improve air traffic control, upgrade the effectiveness and comprehensiveness of aircraft monitoring systems, reduce risks due to both terrorism and aircraft wear-out or malfunction and help to define these new space based systems for global implementation. These systems would possibly supplement or substitute for existing on-board systems but they would, at minimum allow for more real time understanding of problems or hazards associated with aircraft operations, routing, equipment monitoring, and flight control.

It is proposed that an international effort, that would involve Japan, Canada, Australia, the U.S. and Europe, should be undertaken as soon as possible to review and assess the critical technologies needed to support future aircraft safety, upgrade the efficient of airline operations, support increased volumes of aircraft traffic, augment and upgrade airline monitoring systems and also to provide enhanced anti-terrorist protection.

Such an effort would involve many design and system engineering issues with regard to aviation traffic monitoring and control safety standards, sensor definition, information storage and processing requirements, system specifications with regard to security, reliability, and international standardization. The purpose of this paper, however is to highlight particular issues and questions that pertain to finding ways to obtain sufficient bandwidth and usable spectrum to meet the high data rate requirements associated with such a space based aviation traffic control and monitoring system and the antenna design issues associated with the broadband throughput requirements associated with both the satellite and the aircraft terminals. These spectrum and satellite and terminal antenna design issues will be driven by several key systems constraints. These include:

a. Determining a way to greatly increase the amount of information that is available to the aircraft crew on a real-time basis with respect to aircraft monitoring, traffic control, and overall safety while also allowing a much broader band flow of aviation monitoring and safety and security information to flow from aircraft to ground systems. This increase in information flows to and from the aircraft must be accomplished while also either reducing overall operating costs or holding cost increases to a reasonable standards such as no net cost increase of more than $5 to $25 per thousand passenger mile flown.
b. Finding an effective way to communicate and process the substantially greater amount of information generated by this new system so that reliability is not compromised and excessive transmission and/or processing costs are not generated. Further this must be accomplished without increasing the risk of security breaches to the system. (These constraints raise the serious possibility of using pre-processing and artificial intelligence or expert systems so that the amount of information generated, communicated and processed is reduced by a substantial amount).
c. Finding creative and cost effective ways to accommodate the substantially greater amount of information that is sent to and received by the aircraft (including real-time weather information) that must be transmitted within the available mobile aeronautical frequency bands taking into account the increasing number of aircraft flights (and overall passenger miles flown) and the need for great reliability of these systems to meet stringent aircraft safety standards. (Advances in information processing, pre-processing algorithms, satellite communications performance, aircraft antenna systems, spectrum efficiency and security systems are thus all implicit in these considerations.
d. Finally the systems engineering process must address the questions of whether all of these aircraft traffic control, aircraft traffic monitoring and aircraft safety systems will be kept separate from and segregated from passenger entertainment and communications services and to what extent are these services provided via common or separate spectrum bands.

Further Steps

In light of the international nature of aviation and the interest in airline safety and efficient operations around the globe it makes a great deal of sense for the study of such a satellite based air traffic control and airline monitoring system to be coordinated on a global basis. The engineering of these systems could benefit from economies of scale and from common design features if the design and engineering of these systems were carried out on a global basis or even if carried out on a regional basis by airlines that fly in the highest aviation traffic density areas.

Beyond this research, efforts to identify the appropriate spectrum for these applications need immediate attention from a policy perspective. Frequencies in the Ku-band might well hold advantage over millimeter wave because of rain attenuation problems and the need for extremely high reliability. This issue clearly needs prime attention as well.

The design and implementation of new broadband satellite systems for the most part start as satellite manufacturing operations that respond to operators of satellite systems. In this case a major new system that generates a significant new volume of satellite-based traffic could be designed from the perspective of the user needs. It is thus recommended that the satellite community work with the aircraft manufacturing and the aviation industries to see if a highly responsive the space based systems that would with terrestrial computer based systems to create a 21st century network that could save lives, combat terrorism and make aviation systems more cost and fuel efficient.

The next meeting of the Japan-US Science Technology and Space Applications Program (JUSTSAP) that meets in Hawaii in November 2004 might be an excellent forum where this important new space applications program might be discussed and feasibility studies launched to explore these possibilities.

Major Research Agenda for New GeoPlatform Systems to Support Aviation Based Broadband Satellite Services		
No.	**Description of Critical Subsystem For Advanced GeoPlatform Design Evaluation and Selection**	**Criticality (1-5) Status of Design Readiness**
1.0	**Extremely High Efficiency "Rainbow Solar Cells—True Multi-Junction Cells with over 50% Energy Conversion Capability**	**(Criticality--4)** **5 years to in-orbit test**
2.0	**Re-generative, Unitized Fuel Cells with Energy Density Twice That of Lithium Ion Batteries**	**(Criticality-2)** **3 years to in-orbit test**
3.0	**Advanced Satellite coding and modem systems (that offer outstanding new ranges of transmission efficiency (in the 3 to 4 bits/Hz).**	**(Criticality-4)** **2-3 years to in-orbit test**
4.0	**Advanced "Smart Beam" MIMO Antennas and advanced encoding that allows extremely intensive reuse of frequencies (1 in 3 or even 1 in 2 frequency re-use coupled with advanced turbocoding multi-plexing systems**	**(Criticality-4)** **3-5 years to in-orbit test**
5.1	**Large Scale Piezo-Electric Based Parabolic Antenna Reflectors w/ Shape Maintenance Via Electronic Gun Radiation (i.e. 50 meter aperture—5 to 10 meter scale model test)**	**(Criticality-5)** **3-5 years to in-orbit test**
5.2	**Large Scale Polyimide Inflatable Parabolic Antenna (50 meter aperture reflector—10 meter scale model test)**	**(Criticality-5)** **3-5 years to in-orbit test**
5.3	**Cluster of 8-10 Flat MIMO Antennas with Aperture Size of 5-8 meters (Test configuration to be determined)**	**(Criticality-5)** **3-5 years to in-orbit test**

Biography
Dr. Joseph N. Pelton is a Research Professor with the Institute for Applied Space Research at the George Washington University. He also holds concurrent appointments as a Member of the College of Teachers at the International Space University of Strasbourg, France and as Professor of Telecommunications at the University of Colorado at Boulder.

Currently, he heads several international research projects in space communications and frequency allocations at the Institute for Applied Space Research. During 1996/7, he served as Vice President of Academic Programs and Dean of the experimental global virtual university known as the International Space University. This project, with backing from 400 organizations around the world and most of the world's space agencies, has a central campus in Strasbourg, France, along with 24 affiliate campuses. The ISU is also represented on the Space Agency Forum, a group representing NASA, ESA and 35 other space agencies from around the world, and in this role has been requested to develop a model space education program for global implementation.

Dr. Pelton is the author of 16 books in the field of satellites, telecommunications and the long range impact of technology on society since 1975. These include the four book series: Future Talk, Future View, Cyberspace Chronicles and Global Talk, the latter of which he was nominated for a Pulitzer Prize. He is also author of over three hundred journal articles, encyclopedia entries and Congressional testimonies.

Dr. Pelton currently chairs a NASA and the National Science Foundation Panel of Experts that is conducting a global review of satellite telecommunications. This report, the follow on to a similar study panel he co-chaired in 1992, will be presented to NASA, the NSF, other U.S. Government Agencies and Congress in early 1998. He is also serving as a consultant to the French Space Agency and is an official member of the Japanese Government's high level external evaluation committee for NASDA, the Japanese Space Agency.

From 1969 to 1989, Dr. Pelton held a number of management positions with COMSAT and the INTELSAT global satellite organization. These included Executive Assistant to the Director General of INTELSAT and Director of Strategic Policy for INTELSAT. Dr. Pelton is a frequent keynote speaker and has delivered major addresses in over 40 countries and spoken at the UN, UNESCO, ITU, the U.S. Congress, Harvard University, MIT, the AAAS, and at many other distinguished forums. He is a full member of the International Academy of Astronautics, a member of the Who's Who International, the World Future Society, and the AIAA, as well as co-editor of the Journal of Space Communications

Dr. Pelton holds degrees from the University of Tulsa (B.S. 1965), New York University, (M.A. 1967) and Georgetown University (Ph.D. 1971).