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FREE FLIGHT TECHNOLOGY REQUIREMENTS AND LIABILITY ISSUES THAT MAY ARISE FOR EQUIPMENT MANUFACTURERS

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I. WHAT IS FREE FLIGHT?

Imagine a better way.
One that frees you to go your own way.
Choosing your own optimum routes, speeds and flight levels. IFR-direct to any destination. Saving billions of dollars in airline operating costs each year.

THIS DESCRIPTION OF free flight is from a recent magazine advertisement by a leading maker of aircraft electronics.[1] The ad conveys the elegantly simplistic fundamental concepts of free flight. The ad's offer to "imagine" a system accurately describes the current state of free flight as a concept that is merely in the planning stages. The ad also portrays the tantalizing promises of savings that proponents argue will result from the free flight system.

While there does not appear to be a rigorous definition of the term free flight in the United States, it is generally used to refer to a system where control by the Air Traffic Control (ATC) system is eliminated or greatly reduced.[2] As used in this Article,

[1] AVIATION WK. & SPACE TECH., June 24, 1996, at 4th cover (Rockwell Collins Avionics ad).

[2] The RTCA (Radio Technology Commission of America) defines free flight as

> [A] safe and efficient flight operating capability under instrument flight rules (IFR) in which the operators have the freedom to select their path and speed in real time. Air traffic restrictions are only imposed to ensure separation, to preclude exceeding airport capacity, to prevent unauthorized flight through Special Use Airspace (SUA), and to ensure safety of flight. Restrictions are limited in extent and duration to correct the identified problem. Any activity which removes restrictions represents a move toward free flight.

free flight refers to the generic idea of a system where aircraft are under their own control with regard to route selection and flight planning, and the Air Traffic Management system (ATM) is a passive observer of the aircraft and airspace, interacting only to resolve conflicts that present a danger to the aircraft.[3] Free flight is "free" when compared with the conventional ATC system where aircraft are assigned discrete routes and continually interact with ATC via radio communications.[4] There are still elements of control in such a system (that is, at a minimum letting the system know where the aircraft is), control by the ATM system is passive unless there is a need to intervene for safety. European and Asian ATM systems have analogous concepts, as will be discussed further below, but they are known by different names.[5]

This Article will not attempt to comment on the viability of the various free flight proposals. But, the Article will point out the various free flight implementation options as they relate to potential technologies. The purpose of the introductory sections is to set forth some of the various concepts of free flight and the technologies to be used in order to provide a background for a discussion of the liability issues that will face the free flight equipment manufacturers. In the conclusion, the authors suggest that proactive measures may be taken to deal with the potential liability problems that face manufacturers.

II. THE BASIC ISSUES ARISING IN FREE FLIGHT

All forms of free flight need to address the same set of issues. The Air Traffic Management system (ATM) must provide a system of avoiding conflicts (that is, avoiding collisions and situations that can have adverse safety consequences). If a magic box could be put in each aircraft to allow the aircraft to electroni-

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RADIO TECHNICAL COMMISSION FOR AERONAUTICS, FINAL REPORT OF RTCA TASK FORCE 3: FREE FLIGHT IMPLEMENTATION 23 (1995) [hereinafter TASK FORCE 3 REPORT].

3 Some proponents extend the concept to cover the entire flight from push back at departure to parking at the destination. *See* David R. Hinson, The Future of Air Traffic Control: Bringing Free Flight to Global Aviation, Remarks at the Financial Times World Aerospace Conference (Aug. 29, 1996).

4 *See* 14 CFR pt. 91 (1996).

5 The concepts of the European and Asian systems are similar enough that the discussions of technology of free flight apply to these systems. In Europe, the analogous concept is referred to as Program for Harmonized Air Traffic Management Research (PHARE). Kieran Daly, *Flying Into the Future*, FLIGHT INT'L, July 17, 1996.

cally see and avoid all other aircraft, this would be the ideal technology for a true free flight system. Unfortunately, magic boxes do not exist. As currently conceptualized, each of the free flight ATM proposals involve a combination of ground-based monitoring by the ATM agencies of the various nations (the Federal Aviation Administration (FAA) in the United States) and aircraft equipment to communicate with the ATM system and/or issue control instructions the aircraft in a highly automated manner.[6] The ground-based ATM agency must, at a minimum, know what aircraft are in the system, their location, and their route intentions. The ATM system must have the capability either to intervene and issue instructions to avoid the development of a hazardous situation, or, if onboard systems are used to avoid conflicts, the ATM system must be able to monitor the aircraft's compliance with avoidance maneuvers generated by the aircraft's systems.

If rational economic considerations control the decision to select a free flight system, the chosen system must not only resolve all of these problems, but must do so in a manner that will offer economical advantages to significant elements of the aviation community. Absent political considerations, the savings resulting from a free flight system should be at least enough to offset the cost of establishing and maintaining such a system.

If history provides a guide, it would indicate that any free flight system that will be implemented must also be downward compatible. In other words, it must be either capable of dealing with all the aircraft that currently operate in the airspace controlled by the ATM system, or it must control aircraft only in some subset of the airspace in which flight by some aircraft may be prohibited. The system's airborne components must either be cheap enough to be incorporated in all aircraft, or the free flight must control some subset of existing aircraft (such as airline and sophisticated general aviation aircraft) that can afford the necessary equipment. The ground-based components must also exist as either an addition to, or overlay to, a system providing control services to all aircraft. In any event, the free flight system, or the incorporation of free flight as a subcomponent of the ATM system, must provide safe separation for all aircraft using the system in all phases of flight. Unfortunately, the burden of a requirement to include all current types of aircraft in a fu-

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6 RADIO TECHNICAL COMMISSION FOR AERONAUTICS, FREE FLIGHT ACTION PLAN 3 (1996).

ture free flight system is analogous to the implementation of a telephone system based on new technology that must still provide services for rotary dial telephones using copper pair wiring.

The aviation community has witnessed the incorporation of a number of changes to the ATM system in the United States over the years that may serve as examples (both good and bad) as to how free flight technology implementation and downward compatibility might be addressed. Since World War II, the domestic ATM system has absorbed changes to the frequency utilization of the VHF spectrum requiring more complex radios, the development of the current navigational aids system incorporating VOR, DME, ILS, and ADF procedures, and the development of civil airspace restrictions such as Class B and Class C airspace (formerly Terminal Control and Radar Advisory Areas respectively) that brought with them the requirement to use the altitude encoding Mode C transponder.[7] We have recently witnessed the development, and predicted demise, of the LORAN C system for use in aircraft navigation.[8] As most readers are aware, the demise of the LORAN C system is coming about not because the system does not work and does not offer significant advantages over previously used navigational systems, but because the advent of the newer Global Positioning System (GPS) navigation systems in aircraft have made LORAN C a redundant system whose operating expense can no longer be justified.[9] As discussed below, it has been the development of the GPS system that now allows serious consideration of the implementation of free flight systems.

Each of these changes to the ATM system has involved, in one manner or another, the providing of a new service based on new technologies, while retaining provisions to deal with the existing fleet of aircraft, many of which are not, and will never be, equipped with the technology required to implement the newer systems. The current ATM system provides for control over everything from the Space Shuttle to non-radio equipped aircraft.[10] Airspace restrictions provide the first level of control. Unless an aircraft is properly equipped, it must stay out of certain airspace, and those aircraft operating within the airspace are assumed to meet the minimum equipment requirements for

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7 14 C.F.R. §§ 91.130-.131, 91.215 (1996).

8 BILL CLARKE, AVIATION GUIDE TO GPS 76-79 (1994).

9 *Id.*

10 AIRMAN'S INFORMATION MANUAL ch. 5 (1996).

operation.[11] The use of primary radar in addition to transponder returns provides the ATM system with the ability to provide services in areas where aircraft with varying technologies coexist. Even if a non-transponder equipped aircraft allows the FAA to detect and resolve conflicts that may exist between aircraft that are in communication with the control facility, and other aircraft that may or may not be in communication with the control facility.[12]

III. THE DEVELOPMENT OF FREE FLIGHT METHODOLOGY IN THE UNITED STATES

The aviation industry and the FAA have jointly conducted the current planning of free flight in the United States. The Radio Technology Commission for Aeronautics (RTCA), an independent advisory organization that advises the FAA on technology issues,[13] has provided input to the FAA. A subcommittee of the RTCA has been selected to deal with free flight implementation and planning. Its report to the FAA administrator in 1995 provides the current status of free flight thinking in the United States.[14]

IV. THE TECHNOLOGIES ASSOCIATED WITH FREE FLIGHT PROPOSALS

The key development that has led to the serious consideration of free flight is the Global Positioning System (GPS) navigation system. GPS, described in more detail below, offers a method of knowing with great accuracy where all GPS equipped aircraft are located at any time, without the use of radar.[15]

An aircraft's GPS receiver can determine the aircraft's location in space including its altitude, latitude, and longitude.[16] That information can then be automatically transmitted to ground-based computers that track the aircraft's movement, determine whether or not there are projected conflicts with other aircraft, and transmit orders to the aircraft for conflict avoidance.[17] With the increasing power of microcomputers, aircraft

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11 *Id.* ch. 3.

12 *Id.*

13 *See* TASK FORCE 3 REPORT, *supra* note 2.

14 *Id.*

15 CLARKE, *supra* note 8, at 13.

16 *Id.*

17 The free flight system envisions two "bubbles" surrounding each aircraft. These bubbles are called the protected zone and the conflict zone. As the air-

using free flight may perform many of the same calculations as the ground-based computer, and may assume some of the conflict management functions. The ultimate implementation of free flight may use a combination of ground- and aircraft-based computer monitoring/tracking.

One of the key debates that will occur as free flight comes closer to realization is what elements of the current ATM system will need to be retained.[18] One can speculate that a driving function of the free flight proposals is the FAA's desire to eliminate the costly operation of the primary radar systems in the United States as well as the costly manual handling of each aircraft. But, can the current system be completely eliminated? If not, then many of the anticipated cost savings of free flight may prove to be illusory.

In the following sections, the technologies needed to implement the free flight system are discussed. Heavy emphasis is placed on the GPS system because GPS is the key to free flight proposal and is now being rapidly incorporated into the current ATM system.

A. Understanding the Global Positioning System and Its Capabilities

The development of the Global Positioning System (GPS) navigation system makes it possible to consider the implementation of free flight. Therefore, an understanding of the basics of GPS is essential to understanding the technology of free flight.

1. *General Description and History*

The Global Positioning System (GPS) system is a space-based navigational system that uses mid-altitude orbiting satellites as celestial radio beacons, or, as some people prefer, artificial constellations.[19] The transmissions from the satellites allow ground

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craft moves through the system, any intrusion into the bubbles causes the system to react. TASK FORCE 3 REPORT, *supra* note 2, at 29-30.

18 The FAA now projects 2010 as a possible implementation date. Hinson, *supra* note 3.

19 A common misconception is that the GPS satellites are placed in a geostationary orbit. A geostationary orbit is one in which the satellite flies at the speed of the Earth's rotation and thus appears stationary when viewed from the Earth. Orbital mechanics dictate that for a constant velocity satellite to be geostationary, the altitude of the satellite should be about 22,000 miles. For GPS satellites, a lower orbit, at an altitude of about 11,000 miles, is employed and the GPS satellite completes an orbit in about 12 hours. The lower orbit offers better coverage and maintenance options. *See* CLARKE, *supra* note 8, at 4-5.

and airborne radio receivers to process the satellite's signals to determine the receiver's distance from the satellite.[20] The ability to receive data from multiple satellites allows the receiver to unambiguously determine the position of the receiver.[21]

The GPS satellites are owned and operated by the U.S. Department of Defense.[22] A rival Soviet system—GLONASS—was developed. Although interest in GLONASS had faded somewhat due to doubts about Russia's current economic viability and intent, there is currently renewed interest in the GLONASS system.[23] Proposals for the integrated use of GPS and GLONASS would result in increased accuracy.[24] Both GPS and GLONASS were developed for military reasons during the Cold War as a follow-up to earlier satellite navigation systems. Both the United States and the Soviets developed earlier series of navigational satellites (some of which still function) for the purpose of allowing their sea-based ballistic missile launching submarines to accurately update and adjust their onboard inertial navigation systems. These earlier satellites were few in number, and moved in orbits so that they overflew various portions of the earth daily. The U.S. system was known as the TRANSIT series. The accuracy of navigation was adequate, but using the system was fairly complex, as the receiver had to know some fairly complicated orbital information about the satellite and had to "listen" to the satellite a significant period of time. The accuracy of position measurement also depended on the viewing angle of the satellite above the receiver during the overflight. More importantly, navigation could only be performed when the satellites were "visible." Thus, the navigational use was limited to the available overflight time of the satellites.[25] The system was not suitable for vehicles, such as aircraft, that require rapidly updating navigational positioning, nor was it suitable for field use by the Army due to the time-of-use restrictions and the size of the receiver system needed. The TRANSIT satellite's broadcasts allowed for commercial use, but the accuracy of such use was in-

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[20] AOPA AIR SAFETY FOUNDATION, GPS TECHNOLOGY NO. 1. SAFETY ADVISORY 3 (1996) [hereinafter GPS TECHNOLOGY].

[21] *Id.*

[22] CLARKE, *supra* note 8, at 2-4.

[23] Bruce D. Nordwall, *Optimism Grows for GPS/GLONASS*, AVIATION WK. & SPACE TECH., Oct. 14, 1996, at 58.

[24] *Id.*

[25] This information comes from the authors' personal observations with the AN/SRN-9 satellite tracking system employed by the U.S. Navy in the early to mid-1970s.

tentionally degraded by encrypting a portion of the satellite's transmission. Limited commercial use was made of TRANSIT satellites, primarily by commercial shipping operators.[26]

The concept of the current GPS system predated TRANSIT's employment. The decision to implement TRANSIT represented not only the military's operational needs, but state-of-the-art analysis of the satellite and computer technology at the time, as well as the economics involved. Development of the current GPS satellite system had to await funding and further technological development. A fully operational GPS system was not in place until the 1990s, more than twenty years after satellite navigation systems first were used.[27]

2. *The Current GPS System*

The current GPS system has twenty-four satellites (Navigation System by Timing and Ranging, (NAVSTAR) satellites) in orbit.[28] The satellites have a limited life due to onboard failures and deterioration in the space environment.[29] As a result, the useful life of a satellite is estimated at between seven and ten years.[30] Three of the current twenty-four satellites are spares that can be repositioned to replace a failed satellite.[31] All of the currently orbiting satellites were built and designed by Rockwell. Replacement satellites will be provided by Lockheed Martin.[32] Satellites require regular updating from the ground of the material that they provide on a broadcast. Older satellites had to be updated at least every fourteen days, while new satellites only need to be updated every six months.[33]

3. *Operation of the Basic GPS System*

Each NAVSTAR satellite contains atomic clocks, transmitters, solar panels, batteries, and equipment for its own maneuvering and communications with ground control stations.[34] Each satel-

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26 CLARKE, *supra* note 8, at 2.
27 *Id.* at 3.
28 *Id.*
29 *Id.*
30 *Id.*
31 *Id.*
32 *Id.*
33 This is known respectively as "14-day autonomy" and "180-day autonomy," meaning that the satellite can operate on its own for 14 days or 180 days. GPS TECHNOLOGY, *supra* note 20, at 2.
34 CLARKE, *supra* note 8, at 13-22.

lite transmits data that indicates its orbital parameter in space.[35] The GPS receiver on the ground or in an aircraft determines the distance from the satellite based on a signal transmitted from the satellite and it determines the receiver's position in space by knowing where the satellite was located when it transmitted the signal.[36] The range information from one satellite describes a position that could be anywhere on the surface of a sphere centered on the satellite with a radius equal to the distance from the receiver to the satellite.[37] The intersection of the distance data obtained from three satellites is sufficient to determine a position on the Earth's surface, and *four* satellites' data is required to unambiguously determine both altitude and position, the data needed for aircraft navigation.[38]

Currently, many aircraft use Distance Measuring Equipment (DME). DME provides a measurement of the distance from the aircraft to a fixed DME station, usually located at a navigationally interesting point (for example, at a destination airport).[39] In operation, the aircraft's equipment transmits a pulse to the ground-based DME station, and measures the time lapse between the transmission and the return from the ground station in order to determine the distance to the DME station.[40]

In contrast to DME equipment, the GPS receiver is totally passive. The satellites broadcast ranging signal information continuously. In addition to the distance measuring pulses, the satellites transmit data that allow the GPS receiver to determine the satellites' position in space.[41]

The data transmitted by the satellite is of two types. "Almanac" data generally describes the positions of all the satellites while "ephemeris" data gives the exact parameters of a particular satellite's orbit.[42] The GPS receiver downloads the almanac and ephemeris data and stores it in the receiver's memory for processing along with the ranging signal information.[43] The GPS receiver synchronizes its internal clock to that of the various satellites. The receiver then knows the time that the rang-

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35 *Id.* at 16.

36 *Id.* at 21.

37 *Id.* at 19.

38 *Id.* at 19-20.

39 AIRMAN'S INFORMATION MANUAL, *supra* note 10, ch. 1.

40 *Id.*

41 CLARKE, *supra* note 8, at 16-22.

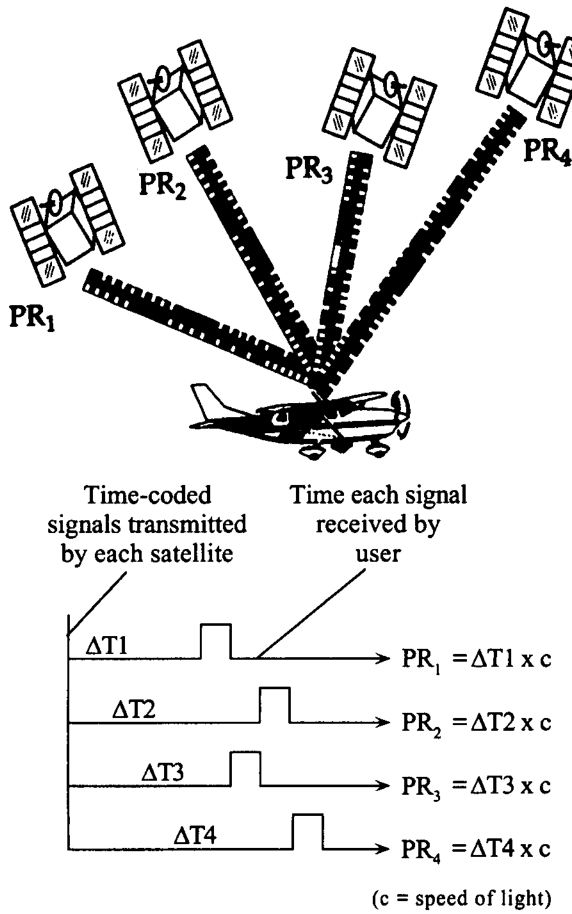
42 DALE DE REMER & DONALD MCLEAN, GLOBAL NAVIGATION FOR PILOTS—INTERNATIONAL FLIGHT TECHNIQUES AND PROCEDURES 203-13 (1993).

43 *Id.*

ing signals left the satellites and the time they arrived at the receiver, and thus determines the ranges to the satellites.[44] Because it also knows where the satellites were when they transmitted the signals, the receiver's position can be determined.[45] (See Figure 1.)

FIGURE 1

A. Data processor obtains pseudorange measurements (PR_1, PR_2, PR_3, PR_4) from four satellites



B. Data processor applies deterministic corrections

PR1 = Pseudorange (1 = 1, 2, 3, 4)

- Pseudorange includes actual distance between satellite and user plus satellite clock bias, atmos-

[44] *Id.*

[45] *Id.*

pheric distortions, relativity effects, receiver noise, and receiver clock bias

- Satellite clock bias, atmospheric distortions, relativity effects are compensated for by incorporation of deterministic adjustments to pseudoranges prior to inclusion into position/time solution process

C. Data processor performs the position/time solution

Four ranging equations:

$$(X_1 - U_x)^2 + (Y_1 - U_y)^2 + (Z_1 - U_z)^2 = (PR_1 - CB \times c)^2$$

$$(X_2 - U_x)^2 + (Y_2 - U_y)^2 + (Z_2 - U_z)^2 = (PR_2 - CB \times c)^2$$

$$(X_3 - U_x)^2 + (Y_3 - U_y)^2 + (Z_3 - U_z)^2 = (PR_3 - CB \times c)^2$$

$$(X_4 - U_x)^2 + (Y_4 - U_y)^2 + (Z_4 - U_z)^2 = (PR_4 - CB \times c)^2$$

X_1, Y_1, Z_1 = Satellite position (1 = 1, 2, 3, 4)

- Satellite position broadcast in 50 Hz navigation message

Data processor solves for:

- U_X, U_Y, U_Z = User position
- CB = GPS receiver clock bias

4. Accuracy and Integrity Issues

The accuracy of the GPS receiver's determination of the distance information is determined initially by the clock rate of the satellite, since the clock rate provides the minimum time interval for measurement.[46] Currently, the resolving capability of the satellite clock is a nanosecond (10^{-9} second).[47] Since the speed of light in vacuo (the speed of a radio signal in space) is approximately 3×10^{10} centimeters per second, if resolution was due only to the ability to measure the clock to its nearest cycle, the GPS system should be able to resolve distance to an uncertainty of thirty centimeters (slightly less than one foot). Unfortunately, real life inaccuracies are larger. In addition to clocking errors, errors in the knowledge of the statellite's orbit, problems caused by transmission through the ionosphere, multipath propagation errors (where refracted signals follow different paths and arrive at the receiver at slightly different times), and

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[46] GPS TECHNOLOGY, *supra* note 20, at 3-4.

[47] *Id.* at 4.

receiver errors, all combine for an overall error of about ten meters.[48]

It is important to understand that the accuracy of the GPS system is quoted in terms of confidence intervals. Generally, the ninety-five percent confidence interval is quoted for the system (the system will accurately report the aircraft's position within the quoted distance ninety-five percent of the time).[49] The confidence intervals are close to one another. As a result, errors outside the ninety-five percent interval are quite close to the ninety-five percent interval limits. Thus, it is reasonable to use the ninety-five percent limits in discussions of GPS system performance and capabilities.[50]

The GPS system was developed with two modes of operation—Precise Positioning Service (PPS) for military users and Standard Positioning Service (SPS) for non-military users.[51] PPS's reported accuracy is twenty-six to thirty meters with ninety-five percent confidence and sixteen meters with fifty percent confidence.[52] The SPS signal is intentionally degraded (the term "Selective Availability" is used to describe the degrading process) to result in a system accuracy of 100 meters with ninety-five percent confidence. In 1996, the Clinton administration pledged that the degrading by Selective Availability would be removed over a four to ten year period.[53] At the time arguments were made that without Selective Availability a terrorist movement or state could use the accuracy of GPS to precisely navigate low technology missiles.[54] These arguments lost to the post-Cold War recognition that the utility of the enhanced GPS precision was of great value. However the military will retain the ability to reinstate Selective Availability in times of national emergency.[55]

Even with SPS's 100 meter accuracy, the basic GPS system is accurate enough for enroute navigation.[56] Its accuracy of approximately 300 feet compares well with VOR/DME accuracy of

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48 *Id.*

49 *Id.*

50 *Id.*

51 *Id.*

52 *Id.*

53 Loring Wirbel, *GPS Heads for New Markets*, ELECTRONIC ENG'G TIMES, Apr. 15, 1996, at 18.

54 *See* Ramon Lopez, *Study Urges Pentagon to Keep GPS Integrity*, FLIGHT INT'L, June 14, 1995.

55 GPS TECHNOLOGY, *supra* note 20, at 4-5.

56 *Id.* at 4.

200-600 feet and to Loran C groundwave accuracy of approximately 600 feet.[57] However, for IFR approaches, the situation is different. GPS's accuracy is poor in relation to ILS accuracy of about fifteen to thirty feet near the runway threshold environment. Therefore, there are add-on fixes to the basic GPS system to improve accuracy and allow for GPS instrument approaches that are discussed in more detail below.[58]

Another issue of great importance to the use of GPS as a primary means of navigation is the integrity of the system. Integrity deals with how it can be determined that the GPS system is functioning properly and providing reliable information to the aircraft's receiver.[59] For the conventional ILS or VOR system, integrity is rather straight forward because there is real-time monitoring of the transmitter's signal quality. If a problem is detected with the ILS or VOR transmitter, the system is shut down and the loss of signal triggers a warning flag in the aircraft's cockpit display.[60] In contrast, integrity determinations in the GPS system are complex. For the GPS system, if only one of the satellites used to determine a fix is unreliable, the entire fix is unreliable.[61] In contrast to the VOR/ILS, there is no steady signal from the satellite from which a deviation can be easily detected. The monitoring of GPS satellites must be done from the ground.[62] If the satellite were to fail totally, there would be no problem, as the GPS receiver would simply use another satellite.[63] But, if the performance level drops due to a small change in orbit or, for example, a problem with signal timing, the aircraft's receiver may sense that the satellite is in a location that is different from its actual location, and induce error into the receiver's calculation of the aircraft's position.[64]

Since detection of the non-reliability of a satellite must be done from the ground, a system must be created that either allows the aircraft's receiver to compute a measure of reliability, or allows the aircraft's receiver to receive real time information on reliability from the ground.

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57 *Id.*

58 *Id.*

59 *Id.* at 4-5.

60 *Id.* at 5.

61 CLARKE, *supra* note 8, at 40-41.

62 GPS TECHNOLOGY, *supra* note 20, at 5.

63 *Id.*

64 *Id.*

5. *Resolving Accuracy and Integrity Problems*

a. Accuracy Corrections

To increase the accuracy of GPS, corrections are made to the GPS signal based on accuracy checks by ground stations. Generally, this is known as Differential GPS or DGPS.[65] Local-Area Differential GPS (LAD) is a variation of the DGPS system, where a local station monitors the various satellites.[66] Since the position of the LAD station is well determined, the station determines its position from GPS and then determines what corrections need to be made to the various satellite signals in order for the GPS position to correctly match the actual position.[67] The LAD station then transmits the local corrections on a low power transmitter for GPS receivers to use to correct the GPS signals in the vicinity of the LAD station. There are a number of methods of transmissions, but the most common is VHF datalink.[68]

LAD systems are capable of five meter accuracy in the correction area and provide the basis for the current GPS approaches to airport used in the IFR situations.[69] With LAD, it is projected that GPS approaches can replace Category I and Category II ILS approaches.[70] The limit of the LAD system area is typically on the order of twenty-five miles. LAD is used at civil airports to provide Special Category I ILS (SCAT-1).[71]

The problems with LAD systems are the need for the local stations and the sophistication required for the local stations. Therefore, LAD is viewed as a short-term resolution of the accuracy problem and a new system called Wide Area Augmentation System (WAAS), described below, is viewed as the long-term solution to both the accuracy and integrity problems.[72]

b. Integrity Solutions

The current resolution of the GPS integrity problem is to force the GPS receiver to use more than the minimum required number of satellites to calculate its position, and then to com-

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65 *See* CLARKE, *supra* note 8, at 35-37.

66 GPS TECHNOLOGY, *supra* note 20, at 5.

67 *Id.*

68 *Id.*

69 *Id.*

70 *Id.*

71 *Id.*

72 *Id.* at 5-6.

pare that position with the position based on the reception of the minimum number of satellites. If the positions are not the same within some acceptable limits of performance, the system is considered unreliable and an alarm signal analogous to the ILS/VOR red flag is displayed.[73] Some GPS receivers can determine which of the satellites is causing problems and "lock out" that satellite to restore accuracy.[74]

The processing procedure in the GPS receiver is called Receiver Autonomous Integrity Monitoring (RAIM).[75] If the RAIM software detects an integrity problem, the GPS receiver will not operate in the approach mode (that is, the GPS receiver cannot be used to make an IFR approach to an airport).[76] It may, however, still be used for enroute navigation. If sufficient satellite reception is available, the RAIM software in some GPS receivers will allow the receiver to perform sufficient calculations to determine the "bad" satellite, lock it out, and proceed in approach mode with reliable satellites, continuing to self-check with RAIM.[77]

The drawback to the RAIM system is that more than the minimum number of satellites need to be used. In some areas, particularly low to the ground where approaches are flown, the GPS receiver may have difficulty in acquiring and tracking more than the minimum required number of satellites due to such things as terrain blocking and antenna alignment. Thus, where the error checking is most needed, RAIM is most difficult to use. In addition, RAIM requires the use of calculational time in the receiver that could be better spent on other problems. There are other cross-checks with the aircraft's other sensors (for example, the altimeter) that can be made to detect integrity problems.

c. Wide Area Augmentation System

Contracts have already been awarded for a system to provide a solution to both the accuracy and integrity problems.[78] The Wide Area Augmentation System (WAAS) will provide a system that will allow GPS receivers to be used for CAT I ILS approaches.[79] WAAS is planned for operation beginning in early

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[73] *Id.* at 5.
[74] *Id.*
[75] *Id.*
[76] *Id.*
[77] *Id.*
[78] *Id.* at 5-6.
[79] *Id.*

1999.[80] The European equivalent to WAAS is European Geostationary Overlay Service (EGNOS).[81] As currently implemented, WAAS operates only with GPS, whereas EGNOS will operate with both GPS and GLONASS.[82]

WAAS will consist of twenty-four ground-based monitoring stations that will constantly be looking at the satellites' signals as they fly overhead.[83] They will feed their analysis in real time to three control stations.[84] Differential corrections and integrity information will be computed and uplinked from the control stations to three geosynchronous broadcast satellites that will broadcast the information to WAAS-equipped GPS receivers.[85] This system will provide sufficient accuracy for CAT I ILS, but for CAT II and CAT III, a LAD system will still need to be employed.[86]

When WAAS is fully implemented, the GPS system will have the potential to allow instrument approaches to be flown virtually anywhere a runway exists.[87] For instance, expensive VOR and ILS facilities will not be necessary, and a vast expansion of civil IFR traffic in the United States may result. The FAA will undoubtedly be faced with requests to implement GPS approach procedures at a large number of airports that have never had an instrument approach. This expansion may result in an interesting set of problems for the ATM system in terms of increasing IFR volume.

B. Getting the Aircraft's Position and Intentions into the Free Flight System

Assuming that each aircraft in the ATM system can process GPS information to provide reliable position information, the next step is to develop the communications system required for the aircraft to communicate with the ATM system. In concept, the ATM system needs to know not only where the aircraft is, but where it intends to go. The current ATM system deals with some of these problems and can provide some guidance regarding the technologies that need to be employed.

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80 *Id.*

81 Nordwall, *supra* note 23, at 58.

82 *Id.*

83 GPS Technology, *supra* note 20, at 5-7.

84 *Id.*

85 *Id.*

86 *Id.*

87 *Id.*

In the current ATM system, the controller is aware of the aircraft's location and is aware of its intentions because the aircraft is on a flight plan, from which it is not expected to deviate. The location element is satisfied by the FAA's radar and transponder systems that provide location and altitude via the Mode C transponder and/or skin returns on primary radar coupled with verbal reports of position from the aircraft.[88] The communication of intentions is done by default. The ATM system tells the aircraft, via the initial flight plan route and subsequent orders from the controller, where the aircraft should go and the controller visually monitors the radar track of the aircraft to ensure that the aircraft is complying with the ATM's instructions.[89]

Obviously, some sort of high-speed, two-way data link will need to be established from each aircraft to the ATM system. Data links are already in limited use, and the use is expanding in the airline sector.[90] Tower data links have recently been incorporated at approximately sixty airports to provide clearance delivery, eliminating clearance read backs.[91]

Currently, there are two data link systems that are in contention for implementation. They represent two different concepts. The first is the Automatic Dependent Surveillance-Broadcast (ADS-B) system and the second is the Mode S transponder. The Mode S transponder is currently implemented with TCAS II hardware and airline pilots already use the TCAS II system to monitor their separation intervals from other aircraft.[92]

C. Management of the Free Flight System

In order to manage the free flight system, the ATM agency will need to develop communications receivers for the data link information and transmission systems to route that data to central computers. These computers will monitor the data, display the data, perform necessary calculations to determine if there are conflicts, and issue either orders to aircraft or alerts to operators (controllers) enabling either or both to respond to and resolve conflict situations. The system will need to have sufficient redundancy and protection against power outages to pro-

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88 *See generally* AIRMAN'S INFORMATION MANUAL, *supra* note 10.

89 Bruce D. Nordwall, *Enabling Free Flight*, AVIATION WK. & SPACE TECH., June 3, 1996, at 28.

90 *Id.*

91 *Id.*

92 *Id.*

vide a safe margin of reliability. Obviously, the overall reliability should be as close to 100% as possible.

The resolution of conflicts involves software calculations of the projected path of *all* the aircraft in the system. This software is often referred to as a "conflict probe."[93] The computer projects vectors for each of the aircraft forward in time to determine points of conflict.[94] In some proof-of-concept systems, the conflict alerts are displayed to a controller who then uses a computer mouse to drag the aircraft's projected track off its present course until the conflict is resolved. The controller then issues a course change based on the computer's suggestion. Obviously the greater the number of aircraft in the system, and the longer time in the future the conflict probe projection goes, the more complex the solution. It can readily be seen that in order to project accurately, the aircraft's intentions must be a known element of the calculation. Furthermore, it is clear that the en-route, high altitude, point-to-point routing is probably the easiest to calculate and resolve since the tracks and projections are relatively stable over long periods of time.[95]

Although conflict probes exist, the free flight system envisioned is well beyond the limitations of current FAA computers, except for limited applications.[96] Therefore, a new computer system will need to be developed for free flight.

V. THE POTENTIAL FOR IMPLEMENTATION OF FREE FLIGHT OR FREE FLIGHT ELEMENTS

There are already quasi-free flight systems. These include the National Route Program and the Negotiated Wind Routes and Ocean Tracking Systems.[97] Therefore, to some extent, free flight is already upon us. These systems involve point-to-point clearances with the pilot responsible for navigation that is not along established airways.[98] For oceanic routes, the entries are

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93 Bill Sweetman, *Free-Flight—The Future of U.S. Air Traffic Control*, INTERAVIA BUS. & TECH., Oct. 1995, at 40.

94 *Id.*

95 TASK FORCE 3 REPORT, *supra* note 2, ch. 5.

96 NATIONAL TRANSPORTATION SAFETY BOARD, NTSB/SIR-96/01, SPECIAL INVESTIGATION REPORT, AIR TRAFFIC CONTROL EQUIPMENT OUTAGES (Jan. 1996).

97 Edward H. Phillips, *Mini-'Free Flight' System to Debut at Atlanta Games*, AVIATION WK. & SPACE TECH., Apr. 1, 1996, at 34; *FAA Launches Free Flight Initiative*, BUS. & COM. AVIATION, Apr. 1996, at 16.

98 Phillips, *supra* note 97; *FAA Launches Free Flight Initiative*, *supra* note 97.

space and time blocked, and the aircraft makes position reports via satellite to indicate that it is conforming to its chosen route.[99]

The National Route Program is similar to the Oceanic system, with ingress and egress points.[100] Altitudes are blocked and to some extent the system (which is currently only for flight above Flight Level 310, with plans to lower the limit to Flight Level 290, and for flight distances greater than 200 miles) probably will form the basis for how the FAA begins to implement free flight.[101] The FAA has estimated that the use of the National Route Program saved the airlines $40 million in 1994.[102] American Airlines has a demonstrated savings of $2.2 million for its Negotiated Wind Routes in conjunction with the National Route Program.[103]

It is typically the American viewpoint that drives free flight, but it must be recognized that other areas, particularly Europe, may leap ahead in the development of free flight concepts if the United States is slow to implement its system. European national authorities generally have greater autonomy than the FAA. Furthermore, there is relatively little opposition to control changes in Europe when compared to the United States.[104] European research organizations have been forging ahead on elements of the Future Aircraft Navigation Systems (FANS).[105] Although many of the elements of FANS are what would be foreseen as equipment for free flight, free flight and FANS are not synonymous. FANS is an architecture of hardware; free flight is an operational control concept that will use the FANS architecture.[106]

United Airlines has already implemented FANS-1 equipment in its trans-Pacific route aircraft.[107] FANS-1 uses GPS location broadcast via satellite to the ATM facility via satellite to provide automatic position reporting.[108]

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[99] Phillips, *supra* note 97; *FAA Launches Free Flight Initiative*, *supra* note 97.

[100] Hinson, *supra* note 3.

[101] *Id.*

[102] *Id.*

[103] *Id.*

[104] David Hughes, *Free Flight Sparks International Debate*, AVIATION WK. & SPACE TECH., July 31, 1995, at 44.

[105] *Id.*

[106] *Id.*

[107] Nordwall, *supra* note 23.

[108] *Id.*

A. What Free Flight Elements Will Most Likely Be Implemented, and on what Timescale

It appears extremely likely that an automated data link will be developed and implemented on a wide scale in the next few years. Although there is some conjecture as to whether ADS-B and/or Mode S will be implemented, data links are already being utilized.[109] GPS is already here, and the implementation of the WAAS system is well underway.[110] Thus, within several years, and certainly by the year 2000, the use of GPS and data link by airlines should be in place and the basic elements needed for free flight will be ready.

The FAA has aggressively stepped forward with a plan to evaluate the free flight concept with testing in Alaska and Hawaii.[111] Starting in 1999 the FAA plans to implement its test.[112] But the full implementation of a free flight system for all aircraft, at all altitudes, and the elimination of the current navigational system of primary radars, transponders, VOR/DME, and ILS system is, in the authors' opinion, perhaps thirty to fifty years away, and may never cover all airspace and aircraft.

Clearly, however, GPS will and probably should rapidly replace Loran C and Omega in the next five years. When WAAS is fully implemented, there would not be much incentive to retain them, even for safety reasons. Similarly, VOR/DME and ILS will probably soon follow. Once GPS is fully implemented it can offer far superior accuracy for enroute navigation and at least the same accuracy (with LADS) for approaches. However, the elimination of primary radar, or beacon radar, and controllers with voice contact may be far off. Although these systems are currently very expensive and free flight advocates envision their elimination, there may be a strong feeling that the ATM system should never be "blind" and should be able to deal with aircraft that, for some reason, can no longer downlink their position (or for that matter have a failure to receive their information). The recent 757 accident near Peru, where a "glass cockpit" may have failed rendering the pilot "blind," may have a lasting impact on

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109 *See id.*; Michael A. Dornheim, *Equipment Will Not Prevent Free Flight*, AVIATION WK. & SPACE TECH., July 31, 1995, at 44.

110 *See* James R. Asker, *GPS Progress*, AVIATION WK. & SPACE TECH., Sept. 2, 1996, at 49. *Hughes Complete WAAS Tests Ahead of Schedule*, AEROSPACE DAILY, Aug. 29, 1996, at 318.

111 Bruce D. Nordwall, *FAA to Use Alaska and Hawaii to Debug Free Flight*, AVIATION WK. & SPACE TECH., Dec. 16, 1996, at 34.

112 *Id.*

public acceptance of a totally computer-based system. Perhaps the ground radar and beacon systems of the future will be different from those now in use, but we may never see a free flight system with radar or voice-radio.

We may also never see a free flight system that encompasses all of the airspace. Instead, we will probably see is a lowering of the National Route Plan levels on a progressive basis. These might drop to some level, say 10,000 feet ASL, that in combination with an AGL criteria may form the "floor" of the free flight domain. Since the primary beneficiaries of the free flight system are high performance, longer-distance aircraft, a separation of free flight capable aircraft from other users, like that which is now performed by Class B airspace, will probably be part of a free flight system.

B. Who Will Build the System?

There are a number of manufacturers of FANS equipment. The authors' impressions are that these are generally the same avionics manufacturers who have built aircraft avionics for years. At the lower end of the price spectrum, however, new digital equipment manufacturers are developing a market share in the avionics area. The questions of who will build the new ATM computer systems and develop the software will be played out over the implementation time of the system. In the wake of the Cold War wind down it is possible that some of the major defense contractors will be free flight system developers.

How the government will contract for such a system or its components is open to debate. If it is the current piecemeal low-bid contracting that hallmarked the failure of the FAA to revamp its computers, then there may be problems. Both the FAA and Congress, smarting from the computer fiasco, might exempt free flight development from normal contracting procedures. This could be done either through special legislation or enhanced oversight which will ensure a development contract where the chosen contractor has sufficient expertise and is granted sufficient control to properly develop and implement the free flight system.

VI. LIABILITY ISSUES FOR EQUIPMENT AND SOFTWARE MANUFACTURERS

A. GENERAL LIABILITY ISSUES FOR MANUFACTURERS OF HARDWARE

This portion of the Article will discuss liability issues facing the manufacturers of components for the free flight system, including those who provide hardware and software for the airborne or ground equipment. This will not be an indepth discussion, but rather an overview of the various theories of liability. This section of the Article will also address the government contractor and the contract specification defenses.

This Article will not discuss liability issues facing the United States government. There is an excellent article in an earlier volume of this journal which provides an analysis of the liability issues facing the United States regarding the expanded civil use of the GPS under the Federal Torts Claim Act, the Suits in Admiralty Act, the Foreign Claims Act, the Military Claims Act, the 1967 Outer Space Treaty, and the 1972 Convention on International Liability for Damage Caused by Space Objects (liability convention).[113]

The manufacturers of GPS satellites and/or related airborne or ground equipment may be liable in tort under various theories of liability just as the manufacturers of aircraft and aircraft components are. In preparing this Article, a study of case law dealing with earlier forms of navigational aids and air traffic control equipment was conducted. The authors' search of the Lexis federal and state databases revealed no cases involving older navigation systems (including ADF, NDB, VOR, TACAN, OMEGA, TRANSIT, or LORAN-C) or air traffic control radar where the manufacturer was held liable under a negligence or strict products liability theory. There are very few reported cases involving the manufacturer's liability for navigational aids, whatever their use.

The only federal case found involving the accuracy or integrity of the GPS was *Connaghan v. Maxus Exploration Co.*[114] The court in *Connaghan* dismissed the accuracy of a survey performed using GPS, concluding that GPS "is only used to aid in

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[113] *See* Jonathan M. Epstein, *Global Positioning System (GPS): Defining the Legal Issues of Its Expanding Civil Use*, 61 J. AIR L. & COM. 243 (1995).

[114] No. 86-CV-0128-B, 1992 WL 535618 (D. Wyo. Feb. 4, 1992), *aff'd*, 5 F.3d 1363 (10th Cir. 1993).

mapping."[115] The lack of cases is probably due to the sovereign immunity of the United States government and to the government contractor defense. But, if the free flight system becomes operational, undoubtedly litigation will follow.

The three main categories of potential liability for manufacturers of products for the free flight system are liability for negligence, breach of warranty, and strict products liability. A brief discussion of each follows.

1. *Liability Based on Negligence*

Under the present law there is no doubt that a manufacturer may be held liable in a personal injury, wrongful death, or property damage case based on a theory of negligence, provided that the negligence was the legal cause of the injury, death, or damage suffered.[116] The negligence may be based on faulty manufacture, faulty design, failure to warn, or failure to instruct.[117]

A manufacturer may be held liable for the faulty manufacture of a product. This theory was raised in the case of *In re Korean Air Lines Disaster of September 1, 1983.*[118] The plaintiffs in the KAL 007 case contended that the aircraft was off course due to a problem in the inertial navigation system (INS). In that case, no liability was assessed against the designers or manufacturers of the INS because the issue was never reached. The court stated that even if faulty manufacture or design could be shown, the defendants would not be liable because of an unforeseeable, intervening cause (the airliner being shot down by a Russian fighter).[119]

A manufacturer may be liable for negligence in the design of a product as well. The Restatement (Second) of Torts section 398 provides:

> A manufacturer of a chattel made under a plan or design which makes it dangerous for the uses for which it is manufactured is subject to liability to others whom he should expect to use the chattel or to be endangered by its probable use for physical harm

[115] *Id.* at *6.

[116] Braniff Airways, Inc. v. Curtiss-Wright Corp., 411 F.2d 451, 453 (2d Cir. 1969).

[117] *Id.*; Moorehead v. Mitsubishi Aircraft Int'l, Inc., 828 F.2d 278, 281 (5th Cir. 1987); LaBelle v. McCauley Indus. Corp., 649 F.2d 46, 49 (1st Cir. 1981).

[118] 932 F.2d 1475 (D.C. Cir. 1991).

[119] *Id.*

caused by his failure to exercise reasonable care in the adoption of a safe plan or design.[120]

A manufacturer may also be liable for failure to warn or for not giving users adequate warnings of known dangerous characteristics.[121] A breach of the duty to warn may also lead to punitive damages against a manufacturer.[122] In the case of *Walter v. Cessna Aircraft*, the manufacturer had known of the increased likelihood of fuel contamination for a number of years. This had resulted in several crashes because of the failure of the manufacturer's fuel tank sump drain to adequately remove water and sediment from the bottom of the fuel tank. The manufacturer had drains available for installation which would correct the problem. Despite the manufacturer's knowledge, it was several years before owners of the affected aircraft were fully informed of the product defect. The *Walter* court held that the evidence in the case was sufficient to warrant an instruction on punitive damages based on the manufacturer's reckless disregard for safety.[123] The appellate court reversed the trial court, which had refused to instruct the jury on punitive damages, and remanded the matter for trial on the punitive damages issue.[124]

A manufacturer may be held negligent for failing to provide information concerning its product. Satellites and the related equipment needed for the free flight system are highly complex devices. Detailed information is required to ensure that they function properly. It is the duty of the manufacturer to supply a purchaser or user with detailed information and instructions on the use of the equipment. Failure to provide proper and sufficient information for such sophisticated devices could cause serious accidents and subject the manufacturer to potential liability.

A manufacturer is normally held to a duty of ordinary care—the care that can be expected of a reasonable manufacturer under the same circumstances. However, in a famous early case, a Michigan court pointed out in its charge to a jury that ordinary care, as applied to an aircraft manufacturer, may be some-

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[120] RESTATEMENT (SECOND) OF TORTS § 398 (1974); O'Keefe v. Boeing Co., 335 F. Supp. 1104, 1120 n.48 (S.D.N.Y. 1971); Smith v. Piper Aircraft Corp., 18 F.R.D. 169, 173 (M.D. Pa. 1955); King v. Douglas Aircraft Co., 159 So. 2d 108, 110 (Fla. Dist. Ct. App. 1963).

[121] *Walter*, 358 N.W.2d at 822.

[122] *Id.* at 824.

[123] *Id.* at 822-23.

[124] *Id.* at 824.

thing more than ordinary care as applied to most other manufacturers:

> The ordinary care that must be exercised is the ordinary care that must be exercised in view of the results which are likely to flow from the failure to exercise ordinary care, and ordinary care in cases where the results of a slip will be slight and unimportant is not sufficient here to fill the requirements of ordinary care for the result of failure to exercise it will be dangerous or destructive to human life. So that the ordinary care which is required to be exercised by the ordinary skillful individual that I have named is the care which is commensurate with the damage which will result if that care is not exercised. And as bearing upon the degree of care which ordinary care implies, the members of the jury are perfectly entitled to consider the possible results or the probable results upon human life of the failure to exercise that ordinary care.[125]

The same is true of the manufacturer of satellites and related equipment for the free flight environment. When considering the possible or probable results for the failure to exercise ordinary care, the loss of hundreds of lives, the standard of ordinary care will be higher than in cases where failure to exercise ordinary care will result in significantly less harm.[126]

A manufacturer might not prevail with a defense that in designing and manufacturing its product it met the standard then generally applicable in the industry.[127] The standard that a manufacturer must meet is the standard of reasonable care and not necessarily the standard of the industry or of other manufacturers in the industry.[128] In another early case standing for this proposition, *T.J. Hooper*, the court held that tugboats were unseaworthy because they did not have radio receivers despite the fact that this was not the custom.[129] Judge Learned Hand pointed out that the general practice is not necessarily a reasonable practice and more may be required than is generally done.[130] When dealing with hundreds of lives which could be lost in a mid-air collision between jumbo jets, relying on a standard in the industry defense is probably not a wise tactic.

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[125] Maynard v. Stinson Aircraft Corp., 1 Av. Cas. (CCH) 698 (Mich. Cir. Ct. 1937).

[126] *Id.*

[127] T.J. Hooper v. Northern Barge Corp., 60 F.2d 737, 740 (2d Cir.), *cert. denied*, 287 U.S. 662 (1932).

[128] *Id.* at 740.

[129] *Id.*

[130] *Id.*

2. Liability Based on Breach of Warranty

In addition to possible liability for negligence, a manufacturer may be liable for breach of warranty.[131] The breach may be of an express warranty or it may be of a warranty implied by law.[132]

Express warranties are warranties made by the seller to potential consumers concerning the quality of the product. The Uniform Commercial Code provides:

> (1) Express warranties by the seller are created as follows:
>
> (a) Any affirmation of fact or promise made by the seller to the buyer which relates to the goods and becomes part of the basis of the bargain creates an express warranty that the goods shall conform to the affirmation or promise.
>
> (b) Any description of the goods which is made part of the basis of the bargain creates an express warranty that the goods shall conform to the description.
>
> (c) Any sample or model which is made part of the basis of the bargain creates an expressed warranty that the whole of the goods shall conform to the sample or model.
>
> (2) It is not necessary to the creation of an express warranty that the seller use formal words such as "warrant" or "guarantee" or that he have a specific intention to make a warranty, but an affirmation merely of the value of the goods or a statement purporting to be merely the seller's opinion or commendation of the goods does not create a warranty.[133]

Thus, an express warranty may be found where the manufacturer, in an advertisement or brochure designed to induce someone to buy a particular product, makes an affirmation of fact or promise. It is possible that a manufacturer's response to a Request For Proposal might contain language which could be construed as an express warranty.

This is another area where there are few reported cases relating to aviation products suppliers. But breach of warranty actions have some advantages over negligence actions because of the burden of proof. Actions based upon breach of warranty allow a plaintiff to avoid the difficult or sometimes impossible task of proving negligence or an unreasonably dangerous defect.

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131 Pegasus Helicopters, Inc. v. United Technologies Corp., 35 F.3d 507, 510 (10th Cir. 1994).

132 *Id.*; *Braniff Airways*, 411 F.2d at 427.

133 U.C.C. § 2-313 (1984).

Some courts still hold that privity of contract is a requirement for an action based upon breach of warranty.[134] The basis for the traditional viewpoint that privity is required is the rationale that the one who makes representations to generate a sale should not be responsible for losses sustained by a stranger to whom the affirmations were not made.[135] This rationale does not apply to a manufacturer who, through advertising, brings the matter to the attention of the general public and in particular, to the person who is harmed by the failure of the product to live up to the representations.[136] Therefore, even in states requiring contractual privity for an action based on a breach of warranty, compelling reasons exist for not requiring privity in an action based on the breach of an express warranty through a general advertisement. Whether a manufacturer/seller has created an express warranty through a general advertisement or some other avenue is a question to be determined by the trier of fact.

In addition to liability based on the breach of an express warranty, there is also the possibility of an action based on the breach of an implied warranty. The two basic implied warranties include the general warranty of merchantability and the warranty of fitness for a specific purpose. The general warranty of merchantability simply means that the product is reasonably fit for the general purpose for which it was manufactured and sold.[137]

To establish a breach of the warranty of fitness for a particular purpose, a plaintiff must show reliance on the warranty and that the seller was aware of the particular purpose and use to which the buyer would put the product.[138] These factors are not required of a warranty of merchantability, which is the usual warranty involved in products liability cases.[139]

One of the major issues with implied warranties is whether a disclaimer of warranty or limitation of remedies is effective against third party plaintiffs.[140] Many authorities take the view

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134 *See* U.C.C. § 2-318 (1984); Rocky Mountain Helicopters, Inc. v. Bell Helicopter Textron, Inc., 24 F.3d 125, 130 (10th Cir. 1994) (citing Texas Processed Plastics, Inc. v. Gray Enter., Inc., 592 S.W.2d 412, 415 (Texas Civ. App.—Tyler 1979, no writ)). *See also* M. STUART MADDEN, PRODUCTS LIABILITY ch. 5 (1988).

135 Fleming James, Jr., *Products Liability*, 34 TEX. L. REV. 44, 48 (1955).

136 *Id.*

137 Wenningsen v. Bloomfield Motors, Inc., 161 A.2d 69, 75 (1960).

138 Cochran v. Rockwell Int'l Corp., 564 F. Supp. 237, 242 (N.D. Miss. 1983).

139 *Id.*

140 *See* L. FRUMER & M. FRIEDMAN, PRODUCTS LIABILITY ch. 3 (1987).

that such a disclaimer of warranty, even if binding on the buyer, cannot be effective against a third person who is not aware of it. Professor James has observed:

> Language must be clear and unambiguous to effect exclusion of warranties, and will be construed strictly against such effect. If, for example, there is an express warranty, and also a disclaimer of warranties, the former controls . . . .
>
> Even where the language is clear, a disclaimer will be ineffective unless it was likely to come to the buyer's attention before completion of the sale. . . . Where there is nothing of that sort—as in the normal retail sales transaction, for instance—there is rarely any question of disclaimers of warranty. . . .
>
> Disclaimers of warranty or of liability for negligence bind only the parties to the transaction and do not bind third parties. Under the usual rule of privity only parties to the transaction may take advantage of a warranty; hence the effect of a disclaimer is as broad as the warranty obligation itself. However, where warranties are given more extensive effect and in all cases of negligence, the present principle may be important. . . . Even a court which recognizes a third party warranty . . . might not follow the same rule in regard to a third party nonwarranty.
>
> Where the effect of a warranty is extended by reason of the maker's advertising addressed to the general public, a disclaimer of warranty clearly expressed in the same advertising should perhaps be given an equally broad effect. But where the disclaimer is in the documents of sale between the maker and his vendee, it should not bind remote vendees.[141]

The fact that sovereign immunity and judicially created affirmative defenses exist to protect suppliers and the United States government will preclude some of these theories of liability. But should the free flight system be "privatized" in some form, they could become viable causes of action in a personal injury or wrongful death case.

3. *Strict Products Liability*

Breach of warranty is a form of strict liability because proof of negligence is not required for recovery.[142] But rules regulating contracts and sales have complicated the law of warranty, making it an ineffective remedy in many cases.[143] As a result, the doctrine of strict liability in tort evolved. The doctrine of strict

141 James, *supra* note 135, at 210-11 n.115.

142 *See* FRUMER & FRIEDMAN, *supra* note 140.

143 *Id.*

liability has been adopted by all American jurisdictions except Delaware, Massachusetts, Michigan, North Carolina, and Virginia.[144] The doctrine has also been embodied in the Restatement (Second) of Torts section 402A, which provides as follows:

> (1) One who sells any product in a defective condition unreasonably dangerous to the user or consumer or to his property is subject to liability for physical harm thereby caused to the ultimate user or consumer, or to his property, if:
> (a) the seller is engaged in the business of selling such a product, and
> (b) it is expected to and does reach the user or consumer without substantial change in the condition in which it is sold.
> (2) The rule stated in Subsection (1) applies although:
> (a) the seller has exercised all possible care in the preparation and sale of his product, and
> (b) the user or consumer has not bought the product from or entered into any contractual relation with the seller.[145]

Ten years after California adopted strict liability in the seminal case of *Greenman v. Yuba Power Products, Inc.*[146], a New York court held that "a manufacturer of a defective product may be held liable to an innocent bystander, without proof of negligence, for damages sustained in consequence of the defect."[147] In extending the protection to innocent bystanders, the *Codling v. Paglia* court wrote:

> In today's world it is often only the manufacturer who can fairly be said to know and to understand when an article is suitably designed and safely made for its intended purpose. Once floated on the market, many articles in a very real practical sense defy detection of defect, except possibly in the hands of an expert after laborious and perhaps even destructive disassembly. . . . We are accordingly persuaded that from the standpoint of justice as regards the operating aspect of today's products, responsibility should be laid on the manufacturer. . . . We take as a highly desirable objective the widest feasible availability of useful, nondefective products. . . . Obviously, if manufacturers are to be held for financial losses of nonusers, the economic burden will ultimately be passed on in part, if not in whole, to the purchasing users. But considerations of competitive disadvantage will delay or di-

144 *See* LEE S. KREINDLER, AVIATION ACCIDENT LAW ch. 5, § 5.04 n.6 (1996).
145 RESTATEMENT (SECOND) OF TORTS § 402A (1974).
146 377 P.2d 897, 900 (Cal. 1963).
147 *See* Codling v. Paglia, 298 N.E.2d 622, 624 (N.Y. 1973).

> lute automatic transferral of such added costs. Whatever the total cost, it will then be borne by those in the system, the producer, the distributor and the consumer. Pressures will converge on the manufacturer, however, who alone has the practical opportunity, as well as a considerable incentive, to turn out useful, attractive, but safe products. To impose this economic burden on the manufacturer should encourage safety in design and production . . . .[148]

When bringing an action for strict products liability, the plaintiff must prove that the product was defective, that the defect caused the injury complained of, and that the defect can be traced to a defendant.[149] But as the doctrine is applied in some states, it is not essential that the plaintiff identify the specific defect.[150] Also, several courts have held that a defect may be proved by circumstantial evidence.[151]

The defective condition of a product is not limited to defects in design or manufacture. The seller must provide, along with the product, every element necessary to make it safe for use.[152] One such element may be warnings or instructions concerning the use of the product. The seller must give such warnings and instructions as are required to inform the user of the product of the possible risks and inherent limitations of the product.[153] Absent such warnings, if the product is defective and the defect is a legal cause of plaintiff's injury, the seller is strictly liable without proof of negligence.[154]

B. Liability Issues for Software of Database Providers

The doctrine of strict liability in tort applies to products placed in the stream of commerce.[155] "Courts have not extended the doctrine of strict liability to transactions whose pri-

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148 *Id.* at 627-28.

149 Swain v. Boening Airplane Co., 337 F.2d 940, 942 (2d Cir. 1964), *cert. denied*, 380 U.S. 951 (1965).

150 *See* Bell Aerospace Corp. v. Anderson, 478 S.W.2d 191, 197 (Tex. Civ. App.—El Paso 1972, writ ref'd n.r.e.).

151 *See id.*; Paul D. Rheingold, *Proof of Defect in Product Liability Cases*, 38 Tenn. L. Rev. 325 (1971); Allan E. Korpela, Annotation, *Products Liability: Proof of Defect Under Doctrine of Strict Liability in Tort*, 51 A.L.R.3d 8 (1973).

152 Berkebile v. Brantley Helicopter Co., 337 A.2d 893, 902 (Pa. 1975) (quoting Restatement (Second) of Torts § 402A)).

153 *Id.*

154 *Id.*

155 Pierson v. Sharp Memorial Hosp., Inc., 264 Cal. Rptr. 673, 675 (Cal. Ct. App. 1989).

mary objective is obtaining services."[156] Courts have also declined to apply strict liability where the transaction's service aspect predominates and any product sale is merely incidental to the provision of the service.[157] "A product is a physical article which results from a manufacturing process and is ultimately delivered to a consumer. . . . [A] service is no more than direct human action or human performance."[158]

Generally, the software or the database utilized in a computer system is considered a service and not goods.[159] Therefore, an action for strict products liability is not normally available for a defect in the software or database. However, the courts, rather than relying on a strict dictionary definition, have adopted an expansive interpretation of the term "product" which will serve the policy reasons underlying the strict products liability concept.[160]

In one area particularly related to aviation, aeronautical charts, the courts expanded the definition, thereby subjecting the provider to strict products liability. In the case of *Aetna Casualty & Surety Co. v. Jeppesen & Co.*,[161] the Ninth Circuit provided this analysis:

> Jeppesen approach charts depict graphically the instrument approach procedure for the particular airport as that procedure has been promulgated by the Federal Aviation Administration (FAA) after testing and administrative approval. The procedure includes all pertinent aspects of the approach such as directional heading, distances, minimum altitudes, turns, radio frequencies and procedures to be followed if an approach is missed. The specifications prescribed are set forth by the FAA in tabular form. Jeppesen acquires this FAA form and portrays the information therein on a graphic approach chart. This is Jeppesen's "product."[162]

Other cases dealing with approach charts have reached the same conclusion.[163] The courts tend to focus on the mass pro-

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156 *Id.*

157 *Id.*

158 *Id.* at 676.

159 *See* Micro-Managers, Inc. v. Gregory, 434 N.W.2d 97, 100 (Wis. Ct. App. 1988).

160 *See* Kaneko v. Hilo Coast Processing, 654 P.2d 343, 348-49 (Haw. 1982).

161 642 F.2d 339 (9th Cir. 1981).

162 *Id.* at 341-42.

163 *See* Saloomey v. Jeppesen & Co., 707 F.2d 671, 677 (2d Cir. 1983) ("Though a 'product' may not include mere provision of architectural design plans or any similar form of data supplied under individually-tailored service arrangements,

duction aspect of Jeppesen's aeronautical charts and on the policy reasons underlying the strict products liability concept.[164] These underlying policy reasons include protecting otherwise defenseless victims of manufacturing defects and spreading the cost of compensation throughout society.[165] Claims against the United States have also been allowed for negligence in publishing misleading aeronautical charts or maps.[166]

The software/database for the free flight system is the critical ingredient for its success. The free flight system envisions a passive role for the air traffic controller who will monitor the system for potential conflicts and evaluate the proposed solution provided by the free flight equipment when an aircraft encroaches upon another aircraft's protected zone. The air traffic controller will only intervene if it does not appear that the equipment has provided a suitable solution to the conflict. Thus, the free flight hardware, driven by the software/database, will be the active component of the system.

It is possible that a defect in the software or the database could allow a mid-air collision to occur even though an air traffic controller had been monitoring the aircraft's flight. Depending upon the nature of the defect and the factual scenario, the plaintiff might not have a viable cause of action against the passive air traffic controller and could be left without a remedy. An accident of this nature would probably result in a court holding that the software/database is a product, not a service, based on the policy reasons stated in the aeronautical chart cases.[167] To hold otherwise would fail to provide protection to the "otherwise defenseless victims of manufacturing defects."[168]

... the mass production and marketing of these charts requires Jeppesen to bear the costs of accidents that are proximately caused by defects in the charts."); Brocklesby v. United States, 753 F.2d 794, 800 (9th Cir.), *amended on other grounds*, 767 F.2d 1288 (9th Cir. 1985), *cert. denied*, 474 U.S. 1101 (1986); Fluor Corp. v. Jeppesen & Co., 216 Cal. Rptr. 68, 71 (Cal. Ct. App. 1985).

164 *See Saloomey*, 707 F.2d at 676-77; *Brocklesby*, 753 F.2d at 800; *Fluor*, 216 Cal. Rptr. at 70.

165 Campbell v. General Motors Corp., 649 P.2d 224, 230 (Cal. 1982).

166 *See* James L. Rigelhaupt, Jr., Annotation, *Liability of United States for Negligence of Person Other Than Air Traffic Controller in Connection with Aviation Control Operations*, 47 A.L.R. 85 FED. (1980).

167 *See Saloomey*, 707 F.2d at 671.

168 *Campbell*, 649 P.2d at 230.

C. Government Contractor Defense

The free flight system envisioned in this Article will be controlled by the United States government and not by free enterprise. Given this concept of the free flight system, it is likely that the United States government will control the acquisition of hardware and software to implement the system. Consequently, a manufacturer of hardware and/or software for the free flight system may raise the government contractor defense (also known as the "military contract defense") as an affirmative defense.[169]

The United States Supreme Court adopted the government contractor defense in *Boyle v. United Technologies Corp.*[170] Under certain conditions, this defense provides protection from state tort liability for design defect claims to contractors who produce products for the federal government.[171]

Although some courts only allow this defense for military equipment, most jurisdictions allow the defense for non-military, but federally procured equipment.[172] An argument could be made that the United States GPS equipment is, in part, military equipment (since the current GPS satellites are military) and that the defense should at least apply to those products procured by the federal government for military use.

The government contractor defense prohibits the imposition of liability for product caused injury or death on those who supply the products pursuant to contracts with the United States, provided certain conditions are met. In order to displace state law there must be: (1) a uniquely federal interest and (2) a significant conflict between the federal interest and the operation of state law.[173] In order for the defense to apply, it must be shown that: (1) the United States approved reasonably precise specifications for the product; (2) the product conformed with the specifications; and (3) the supplier warned the United States about any dangers in the use of the product that were known to the supplier, but not known to the United States.[174]

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169 *See* Boyle v. United Technologies Corp., 487 U.S. 500, 514 (1988).

170 *Id.*

171 *Id.* at 511.

172 *Id.* at 505-07; *see also* Burgess v. Colorado Serum Co., 772 F.2d 844, 846 (1985).

173 *Boyle*, 487 U.S. at 500.

174 *Id.* at 512.

The implication of uniquely federal interests will require that state law be preempted and replaced by federal common law in those areas where uniquely federal interests are committed, by the Constitution and the laws of the United States, to federal control.[175] There are two uniquely federal interests to be considered with respect to government contracts. First, United States government contracts are controlled exclusively by federal law and the liability of the government contractor, although a tort liability, arises out of performance of the contract.[176] Second, the civil liability of federal officials for actions taken in their course of duty is also a peculiarly federal concern and is governed by federal law.[177]

Application of the government contract defense is conditioned upon the existence of a significant conflict between federal interests and the operation of state law.[178] Such a conflict exists where imposition of liability under state law conflicts with the government's exercise of its discretionary functions.[179] In order for state law to be displaced, the duty of care imposed by the state, that is, the asserted basis for the contractor's liability, must be contrary to the duty imposed by the government contract to manufacture and deliver equipment conforming to the government's specifications.[180]

A true conflict between federal and state law exists where the contractor was required, by contract, to utilize an allegedly defective component; the decision to use the product in such case was made by the government; and, that decision was a discretionary function to be protected through application of the defense.[181] The fact of extensive government participation in the design of the product generally provides evidence of a strong federal interest.[182] But even if a defendant contractor demonstrates some conflict between the federal specifications and its state law duty, the contractor must also show that the conflict was significant and that there was a uniquely federal interest in

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175 *Id.* at 504.

176 *Id.*

177 *Id.* at 505.

178 *Id.* at 500.

179 *Id.* at 501.

180 *Id.* at 509.

181 Niemann v. McDonnell Douglas Corp., 721 F. Supp. 1019, 1022 (S.D. Ill. 1989).

182 Kleemann v. McDonnell Douglas Corp., 890 F.2d 698, 701 (1989).

having the conflict resolved in favor of displacing state court law.[183]

The government contractor defense is applicable to claims for products liability based upon principles of negligence.[184] The elements of the government contractor defense remain the same whether the plaintiff's theory of recovery is one of negligence or of strict liability.[185] The government contractor defense is also valid against claims based on breach of warranty[186] and it may be raised against design defect allegations.[187] But the defense is not available in cases involving manufacturing defects. Where the defect is caused by shoddy workmanship and not a defective design, it implicates no federal interest.[188] Whether the government contractor defense would bar products liability claims based on a duty to warn depends upon the factual circumstances.[189]

The free flight system will use GPS satellites which are already in place.[190] These satellites were procured for the military initially.[191] Presumably the satellites were built to specifications provided by the military and any defect would probably entitle the manufacturer to raise the government contractor defense.

The related free flight system equipment, although not built for the military, will still be procured by an agency of the United States government. Depending upon the procurement process utilized to acquire this equipment, the government contractor defense may or may not be available. If procured through the process currently in use, it is probable that the defense could be raised. Whether the facts of the case establish the conditions for application of the government contractor defense is a question for the trier of fact.[192]

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183 *In re* Joint E. & S. Dist. Asbestos Litig., 715 F. Supp. 1167, 1170 (E.D.N.Y. 1988).

184 Tozer v. LTV Corp., 792 F.2d 403, 404 (4th Cir. 1986), *cert. denied*, 487 U.S. 1233 (1988).

185 Dowd v. Textron, Inc., 792 F.2d 409, 411 (4th Cir. 1986), *cert. denied*, 487 U.S. 1233, *reh'g denied*, 487 U.S. 1250 (1988).

186 *Tozer*, 792 F.2d at 408.

187 *Boyle*, 487 U.S. at 511.

188 Harduvel v. General Dynamics Corp., 878 F.2d 1311, 1317 (11th Cir. 1989), *cert. denied*, 494 U.S. 1030, *reh'g denied*, 495 U.S. 942 (1990).

189 Nicholson v. United Technologies Corp., 697 F. Supp. 598, 604 (D. Conn. 1988).

190 GPS TECHNOLOGY, *supra* note 20, at 2.

191 CLARKE, *supra* note 8, at 27.

192 Pietz v. Orthopedic Equip. Co., 562 So. 2d 152, 154 (Ala. 1989), *cert. denied*, 498 U.S. 823 (1990).

D. Contract Specification Defense

The contract specification defense provides that a manufacturer cannot be held liable for producing a product with specifications that are beyond its control.[193] The defense has been said to be based on the presumption that a contractor will lack the experience to evaluate the specifications given to it and, therefore, will not be held to the same high standard of care as a designer.[194] The contract specification defense has its basis in negligence principles and applies to products manufactured to the order and specification of another whether the other is the government or a private party.[195] The government contract defense is not based on ordinary negligence principles and applies only when the product in question has been manufactured pursuant to a contract with the government.[196]

The basic tenet of the contract specification defense is that a contractor is not liable for damages resulting from a defective design where the specifications are provided by another, unless those design specifications are so defective and dangerous that a contractor of reasonable prudence would be put on notice that the product will be dangerously unsafe and likely to cause injury.[197] However, not all jurisdictions have recognized this defense.[198]

This defense could possibly be raised in jurisdictions which do not recognize the government contractor defense for non-military equipment. It could also be raised in cases where the equipment is not being procured by the United States government. But, the defendants who would be defending based on this affirmative defense would undoubtedly be very sophisticated hardware manufacturers and would have a difficult time convincing a jury that they did not appreciate the danger imposed by the contract specifications.

VI. CONCLUSION

The free flight system is still in the conceptual stage, but momentum is growing to have a working system in place as soon as

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193 *Brocklesby*, 753 F.2d at 801.

194 Johnston v. United States, 568 F. Supp. 351, 384 (D. Kan. 1983).

195 *Id.*

196 *Id.* at 353-54.

197 Littlehale v. E.I. du Pont de Nemours & Co., 268 F. Supp. 791, 803 (S.D.N.Y. 1966), *aff'd*, 380 F.2d 274 (2d Cir. 1967); *Johnston*, 568 F. Supp. at 354; Bynum v. FMC Corp., 770 F.2d 556, 563 (5th Cir. 1985).

198 Collins v. Newman Machine Co., 380 S.E.2d 314, 316 (Ga. Ct. App. 1989).

possible. As stated earlier, the FAA is hoping for implementation by 2010. Based on what the authors have learned of the proposed free flight system, it does not appear to provide significant performance and/or safety benefits in the approach and departure phases near airports, the areas where most accidents occur. By expanding the potential use of instrument approaches to a greater number of airports, the potential for accidents may even increase on a per flying hour basis. If IFR operations increase, the number of accidents will increase even if the accident ratio stays constant. The system does not address the removal of positive ATM radar control during these critical phases. At best it provides enhanced freedom in the cruise portion of flight. But if the free flight system is implemented, no doubt continued research and efforts will be directed towards removing as much ATM control as possible, even in the airport environment.

Since the free flight system is just an idea, now is the time to address potential liability issues facing the manufacturers of hardware and software for the system. If some form of immunity or some means of limiting damages is built into the procurement of the free flight system equipment, the cost of implementing free flight should be greatly reduced. If the manufacturers know their liability position beforehand, they should be able to reduce the cost of the system's components because they will not need to pass through the cost of liability insurance or self-retention defense expenses. The government contractor defense, described above, may provide immunity, but specific legislation addressing liability issues associated with the free flight system would have a more significant impact.

The free flight concept has many benefits if created properly. In addition to the ultimate goal of improving safety, the free flight system should reduce operating costs for commercial carriers. In an ideal world, these savings would be passed on to the consumers and we all would benefit. The time to address liability issues is now, not after the system is operational and the first major catastrophe has occurred.