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Comments on Traffic Control of Space Vehicles

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COMMENTS ON TRAFFIC CONTROL OF SPACE VEHICLES

By R. Cargill Hall†

I. Introduction

SINCE the beginning of the Space Age in 1957, the number of spacecraft launched each year by the two major space powers has risen at a constantly accelerating rate.[1] Under present stated policies, both the United States and the Soviet Union are committed to further space exploration; moreover, a number of other countries have announced their intention to join in launching space satellites.[2] As manned and unmanned multination space traffic increases about the earth and between the earth and its immediate celestial neighbors, international problems will be created involving uneconomic interference among these vehicles as well as questions relative to the proper conduct of a state's activities in this region. These problems, inherent in the exploration of outer space, are similar to the difficulties generated by increased traffic and the use of larger and swifter vessels on the high seas more than a century ago. As international codes for maritime traffic and naval warfare subsequently were developed to regulate and prescribe activity on the world's oceans, it is reasonable to expect that some form of international control also will be adopted among nations to regulate and promote standards of safety for the increasing traffic and diverse activity in outer space.

This article will investigate the need for traffic control of space vehicles and will review currently available control techniques and procedures. In addition, probable flight data requirements necessary to operate an inclusive, uniform control system will be established. Finally, two methods for organizing a feasible traffic control system will be examined, and a recommendation will be made for that method which the author believes to be most adequate.

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[1] Eighteen launches were attempted in 1958, 34 in 1960, and 79 in 1962 (including three international flights in the latter year). During 1964, 92 launches were attempted, and 108 satellites were placed in orbit about the earth or in deep-space trajectories. The launch rate last year amounted to more than one flight into outer space every 4 days. Figures on total space flights were derived from TRW Space Technology Laboratories' *Space Log*, Vol. 4, No. 4, Winter 1964-65, pp. 34 ff.

[2] In December 1964, Italy launched its first earth satellite; United States booster rockets were used. A West European consortium of states (European Launcher Development Organization) plans to engage in earth satellite launch activity in the mid-1960s, and Egypt and France both have independent satellite flights scheduled for the same period. Japan, Israel, and Communist China also recently announced plans to launch earth satellites in the late 1960s.

II. Space Traffic Congestion and Existing Space Traffic Controls

Traffic in outer space, including spacecraft capable of changing orbits, will increase significantly in future years as technological advances continue to spread throughout the industrialized nations of the world, as satellite launch systems become more dependable and less expensive to fabricate, and as the practical applications for satellites are developed. Two undesirable situations can be anticipated to result from this phenomenon:

1. Without regulation of increased space traffic, eventual collisions between spacecraft, between spacecraft and aircraft, or between spacecraft and derelict objects (debris or abandoned craft) are highly probable; and
2. In the absence of any traffic control, heightened international tension and possible accidental conflict may occur among states engaged in the exploration of space.

The latter events may be initiated as a result of erroneous assessments of the nature and intent of unannounced space activity, or by the sudden destruction of a nation's satellite through collision with another object.

If these situations are to be avoided, adequate traffic control regulations for space vehicles[3] must be adopted which will (1) permit continuous safe navigation in outer space and in airspace (by preventing collisions of the type previously described), and (2) ensure a comprehensive capability for national defense by providing accurate data on all activity conducted in outer space.[4] A survey of existing procedures that may be employed to achieve these necessary conditions—under circumstances of developing space traffic congestion—confirms the need for an inclusive system of traffic control for space vehicles.

A. *Navigation In Outer Space*

The terms "navigation in outer space" and "spacecraft navigation," as used here, denote that technique used to establish and maintain the coordinates of a spacecraft placed in orbit about the earth, or one that is placed in a precalculated trajectory to neighboring celestial bodies in our solar system. The spacecraft must conform to a previously established ephemeris constrained by physical laws and influenced by such variables

[3] "Space vehicles," "spacecraft," and "satellites" are here interpreted to include: (1) last-stage booster rockets injected into orbit or beyond, (2) craft housing payload-experiments, and (3) aerospace craft of an advanced X-15 type or of a lifting-body reentry configuration which may "fly" in the atmosphere as well as orbit the earth in outer space.

[4] Regarding national defense in outer space, a complementary world-wide system for monitoring ballistic missile launch activity also will be required as more states come to possess these long-range rockets coupled with nuclear and thermonuclear explosives. France, for example, expects to have twenty-five ballistic missiles in an operational status by 1970 "armed with 250 kiloton warheads and under control of the same strategic command which will operate the Mirage IV Mach 2 bombers." *France To Have 25 Operational Ballistic Missiles By 1970*, 9 Missile/Space Daily 158 (2 Oct. 1964). Egypt, Israel, and Communist China have the capability to develop and eventually produce long-range rockets in addition to the United States, the U.S.S.R., and the West European states. The threat of nuclear conflict initiated by a "third state" will grow in proportion to the number of new states gaining control of these devices, their respective "world-view," and internal political stability. A world-wide spaceborne detection system designed to monitor long-range (IRBM-ICBM) ballistic missile launch activity including points of origin, direction of travel, and distance traveled will become necessary; this is, however, a subject of other studies.

as aerodynamic, magnetic, or gravitational forces. It is not navigation in the classic sense, in which aircraft or ships are directed over a course between two points avoiding climatic interferences and similar contingencies.[5]

With spacecraft navigation constrained by physical laws, it may be argued that the probability of collisions between spacecraft is negligible in the vastness of near-earth space, especially if the positions of vehicles in orbit can be fixed and projected into the future. Often overlooked are the facts that (1) there are existing technical limitations on the size and number of objects that can be tracked on orbit and (2) most space traffic about the earth is concentrated in a zone below or in the lower reaches of the radiation belts (from 100 to 400 nautical miles), in a torus embracing all polar orbits, and in a torus encompassing all low-inclination orbits.

Space traffic and the mounting accumulation of debris in orbit (less material reentering the atmosphere) has already begun to create traffic congestion in this near-earth region. In March 1965, two orbiting Soviet cosmonauts reported that they "cried out in surprise" upon viewing a man-made satellite pass within a mile of their own craft.[6] More recently, in June 1965, United States astronauts White and McDivitt also reported seeing and photographing several satellites while in orbit.[7] During the last three years the amount of debris in orbit alone "has been increasing at the rate of fifty per cent per annum."[8] (A cumulative percentage increase is assumed.) The quantity of this space "junk" has reached sufficient proportions to permit experimenting with techniques for bouncing radio messages between two points on earth by utilizing the larger pieces of debris as reflectors.[9] This increase of traffic and debris in the near-earth region has been confirmed by the Department of Defense. Satellite observations processed by the North American Air Defense Command in mid-1965 rose "to 350,000 per month compared with 209,000 per month a year ago."[10] Space traffic congestion will shortly pose a significant problem for navigation in outer space by raising the probability of collisions; and even "infrequent" collisions in outer space or in airspace would prove disastrous both materially and politically.

As spacecraft pass through airspace as well as through outer space,[11] unlike aircraft or ships which move in a single environment, damages resulting from the collision of space vehicles may be sustained in either or

[5] Popular descriptions of "ships of space plying spacelanes," etc., are inaccurate and misleading. Not until man possesses the capability for intragalactic and intergalactic space travel will navigation in outer space approach true navigation.

[6] Radio news reports, 22 March 1965. This may have been their own booster rocket although one would not think this would occasion "surprise."

[7] Radio news reports, 5 June 1965.

[8] *Communications Via Space 'Junk' Studied in U.K.*, 13 Missile/Space Daily 179 (3 June 1965). *Cf.* note 10 *infra.*

[9] *Ibid.*

[10] *NORAD Satellite Observations Increase*, 14 Missile/Space Daily 7 (1 July 1965). The article states that although the increased observations are due primarily to "growing space traffic, it also reflects improved space surveillance." The total number of man-made objects in orbit about the earth (as of late June presumably) is given as 613.

[11] For want of international agreement, "outer space" remains undefined for legal purposes. Recent opinion expressed by international jurists indicates increasing favor for establishing a "low" boundary falling somewhere between 50 and 100 miles altitude.

both areas of movement as well as on the ground. To regulate or at least monitor the traffic of space vehicles, flight information must be provided on their operations in both these areas. At present there is no known single national or international activity devoted to collecting and disseminating navigation data on spacecraft and to regulating the traffic of space vehicles in both spheres. There are, however, two programs which provide incidental information that may be employed for spacecraft navigation purposes. The first source consists of a United Nations open registry of all space vehicles launched, and the second is derived from a Space Detection and Tracking System operated by the United States.

In December 1961, the United Nations General Assembly adopted Resolution 1721. Part B of this resolution calls upon "all States launching objects into orbit or beyond to furnish information promptly to the Committee on the Peaceful Uses of Outer Space, through the Secretary-General, for the registration of launchings," and requests that "the Secretary-General . . . maintain a public registry of the information furnished. . . ."[12] In their work *Law and Public Order in Space,* McDougal, Lasswell, and Vlasic note that the apparent ambiguity in the wording of the resolution led to varying national interpretations of the resolution's requirements. Questions were raised over (1) the necessity to report unsuccessful as well as successful launches, and (2) whether launches should be reported before or after a flight has taken place. In the first instance, the United States held that it was necessary to report "only those objects which have attained orbit, and remained there. . . ." Other states maintained that all spacecraft launched should be registered, a position favoring development of the most comprehensive listing possible under the resolution. A few months later, "submitting to pressures, sometime in mid-1962, the United States commenced reporting also the launching of those vehicles which did not achieve orbit."[13] The Soviet Union, on the other hand, has consistently failed to include any data on unsuccessful satellite launches. In regard to the latter question, both the United States and the Soviet Union have been announcing spacecraft launches after the fact;[14] however, they normally do provide advance warning to affected public agencies that a launch will take place.[15]

Resolution 1721 also does not specify exactly what kind of spacecraft launch information need be submitted for the register. In spite of this,

[12] U. N. General Assembly Resolution No. 1721 (XVI), 20 Dec. 1961, *International Co-operation in the Peaceful Uses of Outer Space,* Part B. In a subsequent resolution, No. 1962 (XVII), 13 Dec. 1963, *Declaration of Legal Principles Governing Activities of States in the Exploration and Use of Outer Space,* reference is made in Paragraph 7 to further independent registries maintained by individual states, declaring that "the State on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and any personnel thereon, while in Outer Space." *Cf.* Committee Report, ABA Committee on the Law of Outer Space—1965 2.

[13] McDougal, Lasswell & Vlasic, Law and Public Order in Space 573 n.165 (1963).

[14] *Id.* at 594.

[15] The United States provides advance warning for aircraft and ships in the launch vicinity. The Range Control Officer assigned to the Atlantic and Pacific missile ranges informs the FAA and the Coast Guard of the date, time, and "hazardous areas" specified for each proposed launch. The FAA and the Coast Guard, in turn, alert national and international air carriers and ships of those areas where satellite/missile launching and surface impact of spent upper stages is scheduled to occur. Similar procedures are known to exist in the Soviet Union.

data presently reported by the United States and the Soviet Union are similar in nature, including the "name or international designation of spacecraft, date of launching, angles of inclination to the equator, and apogees and perigees of each reported spacecraft."[16] The Soviet Union provides a brief and rather vague statement as to the spacecraft mission; the United States is a little more specific, placing flights within given categories and also adding the type of booster launch combination employed and orbital-decay data on past flights. Accordingly, the current United Nations launch register offers only limited information on the date, time, and trajectories of spacecraft launches from which, primarily, launch totals and orbital success rates for the United States may be ascertained. Although the launch register generally is recognized to establish nationality and jurisdiction for registered craft (in itself a major achievement), it is not a usable source of information for determining realtime space traffic patterns or for regulating this traffic in airspace and in outer space.

More complete space navigation information may be obtained from the North American Air Defense Command (NORAD) in the United States. Under NORAD direction, an independent Space Detection and Tracking System (SPADATS) is maintained for defense purposes to detect, track, identify, and catalog all satellites and orbiting metallic debris by means of a "world-wide sensor system which provides data to the SPADATS center located in the NORAD COC at Colorado Springs."[17] While not intended as a source of information for space navigation, SPADATS does provide important navigation data on orbital parameters, calculated rates of orbital decay, and projected future trajectories for all observable objects. However, the system faces formidable difficulties as a result of increasing traffic in outer space. These include:

1. massive data processing and correlation problems created by the mounting number of articles to be accounted for;
2. the technical limitations of existing skintrack radars which cannot distinguish between small metal objects located close together or stacked one above another; and
3. the fact that certain objects that do not reflect a radar impulse, such as plastic nose fairings, are not observable.

The introduction of vehicles that can change orbits further complicates tracking and correlation difficulties.

Existing national and international capabilities are not sufficient to account for the increasing spacecraft activity and accumulating debris in earth orbits, and to provide an agency which will accept flight plans and furnish accurate, uniform space navigation data. If the states engaged in space exploration fail to plan and establish a space traffic control system with these provisions, then by default they will have maximized the incidence of future spacecraft collisions with the attendant loss of costly experiments and, quite possibly, the lives of astronauts.

[16] McDougal, Lasswell & Vlasic, *op. cit. supra* note 13, at 573-74 n.165.

[17] DMS Market Intelligence Reports, Rockets, Missiles, and Spacecraft, *SPADATS, SS-496-L*, p. 1. COC stands for Combat Operations Center.

B. *Military Defense In Outer Space*

Further consideration of national defense emphasizes the need for a universal space traffic control system. The high speeds and correspondingly foreshortened warning times inherent in military space operations make it imperative to achieve early identification of the number, type, and probable mission of foreign spacecraft in orbits traversing the United States in order to ascertain that these vehicles are not intended for, or engaged in, belligerent acts against this country. This function, involving identification, correlation, and cataloging of spacecraft, is now the responsibility of SPADATS in the United States.

SPADATS, formed in the late 1950s after the launch of Sputnik I, is composed of two principal field components. The first is the Air Force Spacetrack, a series of radar installations located across North America, originally operated under the Advanced Research Projects Agency (ARPA) with headquarters at Hanscom Field, Massachusetts, its purpose being to identify, analyze, and catalog satellite orbital data. The second major SPADATS component is the Navy's Space Surveillance System (SPASUR), a north-south satellite tracking network extending down the east coast of North and South America, first developed for the Vanguard satellite program and known as Minitrack. SPASUR, which can detect non-radiating satellites out to three thousand nautical miles in space, originally fed satellite orbital data into the Air Force-ARPA Spacetrack system.[18]

In 1960, the Air Force-ARPA system was expanded and consolidated under the direction of the North American Air Defense Command and redesignated SPADATS, with headquarters relocated to the NORAD Combat Operations Center at Colorado Springs. Data on orbital parameters for vehicles and debris detected in orbit from both Spacetrack and SPASUR sources are transmitted to the Combat Operations Center, where a computer analyzes, sorts, matches, correlates, and places into inventory all the information gathered on individual objects observed. Later, the computer can produce a summary of information collected for all orbiting objects, predict their future locations, and advise sensors of the expected time of the object's appearance at these locations. SPADATS, operated by the 1st Aerospace Surveillance and Control Squadron of the Continental Air Defense Command under NORAD, became semi-operational in late 1961. Combat Operations Center headquarters under Cheyenne Mountain was scheduled for completion in mid-1965.[19] As presently constituted, SPADATS can obtain orbital data that may be used to target antisatellite missiles for launch against hostile spacecraft; but it cannot determine the precise mission of foreign spacecraft, and it remains confronted by a number of technical problems (as previously noted) which will be compounded as additional states engage in space operations.

Looking beyond SPADATS, determining the mission of spacecraft may

[18] *Ibid.*
[19] *Ibid.*

be accomplished by creating (1) a national or international force of satellite inspector spacecraft, and (2) a universal traffic control system for space vehicles. Satellite inspector spacecraft orbited by each of the major states eventually will police outer space for defense purposes, since agreements for onsite inspection of vehicles prior to launch cannot be reached under present international conditions. These inspector vehicles will embody such features as maneuverability and long life on orbit; however, they will be very expensive to develop and maintain at operational status in any quantity. A formal and inclusive space traffic control system, incorporating preflight registration and mission identification together with the filing of flight plans and the corroboration of postflight data and tracking, could be supplemented by periodic national or international inspector missions to ensure compliance with traffic control and defense agreements. A universal control system of this nature would greatly restrict, if not proscribe, the opportunity for covert offensive action conducted in and from outer space. It would provide defense agencies with complete information on the status of orbital systems at a smaller financial cost than equivalent tracking and inspector efforts implemented by each state on an independent basis. A modified national SPADATS, its task facilitated by an international control system, would still be desirable as a backup operation. From the standpoint of national defense, an inclusive system of traffic control of space vehicles would prove a valuable asset.

Traffic control of space vehicles has been shown to be needed and desirable for reasons of spacecraft navigation and military defense; however, the security content of the information required to operate such a system is critical to a final acceptance of a universal control system among states. The *quid pro quo* exacted from each member nation party to an international agreement to create such a control system consists of the *disclosure of certain preflight and postflight data* to a special control center or centers. The national-security value of this flight information as it affects the defensive preparedness of these states will determine whether the beneficial or jeopardizing aspects of the data disclosed will predominate in an evaluation by the respective governments. It is important, therefore, to review these probable data requirements with an eye to their security implications.

III. Proposed Flight Data Requirements

The flight data requirements necessary for an agency (or agencies) to account for and to regulate the traffic of space vehicles in airspace and in outer space are grouped below in two categories: (1) prelaunch registration and (2) postlaunch data. (A complete list of these principal data appears in Tables 1 and 2.) The particular arrangement of data within each category corresponds roughly to the time-event sequence of spaceflight operations.

A. *Prelaunch Registration*

Prelaunch information is further subdivided into two categories:

a. Filing of Registration and Identification Papers

b. Filing of Flight Plan

Data under a. are composed of spacecraft status and mission information, including (1) flag state ownership papers, (2) whether public or private craft, (3) spacecraft identification markings and characteristics, (4) whether craft is manned or unmanned, (5) purpose of mission, and (6) electronic frequencies utilized. These data provide information necessary to establish nationality and liability, and to ensure that no belligerent activities are initiated from outer space—the second function of space-vehicle traffic control. They also include information that would be required for rescue operations involving manned vehicles; as different countries use varied equipment, international rescue work will require knowledge of these systems. Considerations of national self-interest and national security are most critical for data released under this category. Items (3) and (5)—and, in certain instances, (6)—consist of information not currently obtainable unless disclosed by the launching state. The nature of these data as they relate to military space vehicles dictates that they would be furnished only reluctantly, if at all, under present international conditions. Further East-West political adjustments must precede agreements for filing registration and identification papers which contain substantive mission information. Universal space traffic control arrangements that provide defense information on activity in outer space will have to await this development.

Category b. Filing of Flight Plan, is another matter. It consists of data which are required for the navigation aspects of space flight: (1) launch location; (2) planned launch date, time, and trajectory; (3) planned orbital parameters; (4) planned lifetime on orbit/in space; (5) planned reentry and recovery; and (6) planned disposition of booster vehicles and payload(s) on orbit/in space. Except for segments of item (5), all of this information may be presently obtained or approximated with a SPADATS-type operation. Since these data are obtainable and their national-security value is, therefore, not overriding, international agreements to furnish flight-plan information would appear to be a realizable goal. The exchange of this information would represent significant and tangible progress toward creating the conditions for safe navigation in space, and would afford distinct benefits to the participating states by reducing the chances for physical interference between spacecraft, between spacecraft and debris, or between spacecraft and aircraft.

B. *Postlaunch Data*

Postlaunch data are basically an extension of category b. discussed in the preceding paragraph. They are composed of reprojected or final flight-plan data furnished after launch; that is, (1) actual launch date, time, and trajectory; (2) actual or reprojected orbital parameters; (3) actual or reprojected lifetime on orbit/in space; and so on. As flight information, it is concerned primarily with the navigational aspects of space traffic control and does not involve the restrictive security implications that obtain in filing registration and identification papers. Assuming that prelaunch filing of flight-plan information is found acceptable among nations from the standpoint of security, then acceptance of corroborating postlaunch flight data should pose no serious difficulty.

What may be concluded from this brief review of proposed flight data requirements is that data pertaining to spacecraft navigation is the least restricted, in terms of its security content, for exchange among states. Agreements to exchange flight information and to establish traffic control of space vehicles would appear to be most readily achievable in this particular area. Developing this premise in the concluding section, two methods for organizing an inclusive traffic control system are examined, and a recommendation is made for that method which the author believes to be best suited to the task.

IV. Suggestions for Organizing Traffic Control of Space Vehicles

In investigating the organization of a space traffic control system to achieve safe navigation in outer space, two primary alternatives may be discerned. Eventual control systems may be devised and implemented independently by each state engaging in the exploration of outer space with provisions made for the exchange of flight data, or a single collective system may be created by agreement among these states. It is the author's belief that the latter course of collective action would provide the most efficient traffic control system for reasons that will become apparent in the following analysis.

The reader should keep in mind that any traffic control system for spacecraft navigation purposes would also enhance the defense preparedness of member states by providing traffic data on all spacecraft. Nevertheless, because information on spacecraft missions would not necessarily be made available, these states would maintain whatever backup space defense operations were required to satisfy their respective governments that no belligerent action is contemplated or is in the process of being initiated from the orbital space systems.

A. *A Decentralized Space Traffic Control System*

Assuming that agreements are concluded for international exchange of flight plan information, an inclusive traffic control system organized on a decentralized national basis would be comprised of interdependent and redundant SPADATS-type operations which, in this case, would be devoted specifically to spacecraft navigation tracking and control. A function of this nature will be designated "Astronautics Navigation Tracking and Control System" (ANTACS). Each state participating in the exploration of space and adhering to multilateral agreements for the exchange of flight data would establish and maintain its respective ANTACS (including tracking and acquisition stations, as well as an ANTACS control center). An international agency with a permanent secretariat need not be created. The decentralized national ANTACS would be arranged along the lines shown in Figure 1.

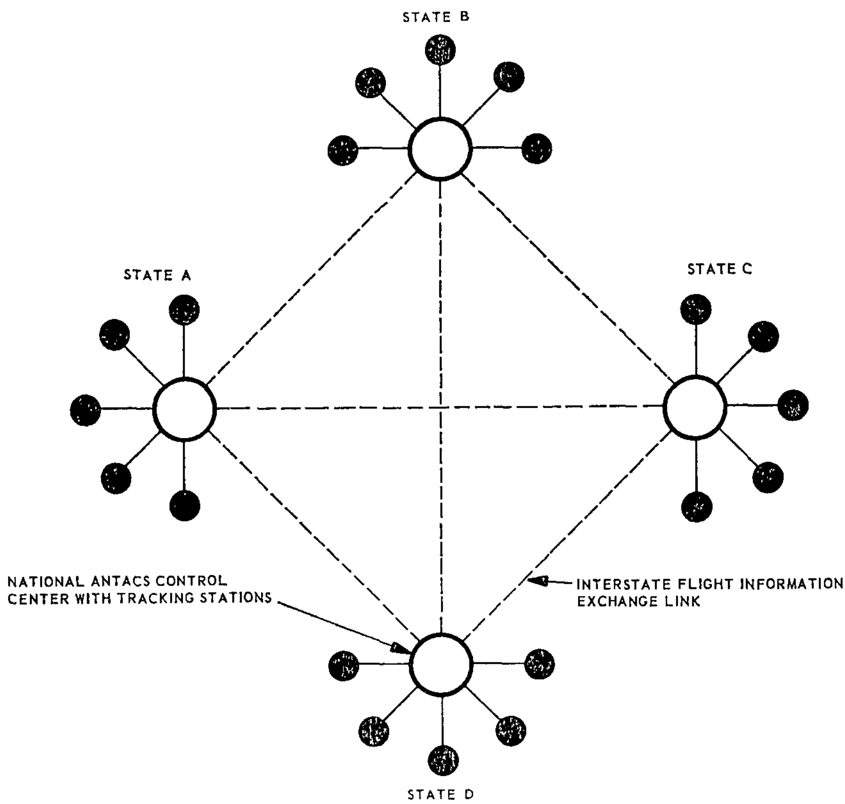

Fig. 1 A Decentralized Space Traffic Control System

Interchange of prelaunch and corroborative postlaunch flight information among all the national ANTACS control centers would greatly enhance safe navigation in space. Compliance with the agreements could be secured by provisions for penalties to be assessed against any member failing to disclose flight plan information before or after vehicle launching, and by convention-authorized inspector missions which could be mounted by the states most concerned to determine the nationality and mission of unidentified craft.

The principal advantage of a traffic control system composed of decentralized ANTACS is the relative autonomy and the complete control exercised by each state over its segment of the system. This attribute would be especially attractive to the larger states which are, by virtue of their stronger economic and technological positions, less severely affected by the disadvantages of decentralization. These disadvantages include the high cost involved and disruption to the system that would be caused by withdrawal of one or more member states. In the first instance, the magnitude of the financial outlay required for a satisfactory national ANTACS (including control center, tracking and acquisition stations, equipment, personnel, and maintenance) probably would preclude all but the major powers from full participation. Distrust might be created among the middle powers if they were required to furnish flight data without possessing the capability to fully substantiate figures which are supplied them in return.

Disruption of the system would occur if any state withdrew from the agreement and withheld flight-plan information. This would place the burden upon the remaining members to search for and locate, independently, the unannounced flights in order to obtain the necessary navigational flight data for exchange. Without a coordinated plan for radar search and acquisition of these flights, the efforts of the remaining national ANTACS would become completely redundant. In this event, a decentralized space traffic control system would be little better than no system at all.

B. *A Centralized Space Traffic Control System*

A universal space traffic control system would be established most successfully by creating a single international agency to which all states participating in space exploration would adhere. Such an organization would be roughly analogous to the present International Civil Aviation Organization (ICAO) in its structure, and it also could be affiliated with the United Nations. For the present discussion, this hypothetical traffic-control body will be termed the "International Astronautics Organization" (IAO).

The astronautics navigation tracking and control function for all states would be conducted by an IAO-ANTACS Control Center. Tracking and acquisition stations, while reporting directly to the IAO-ANTACS Control Center, could remain under control of the individual states or sufficient tracking and acquisition stations to support the system could be transferred to IAO jurisdiction. In turn, required satellite inspection missions could be undertaken by the states concerned, or an international satellite inspector force could be created under the IAO to investigate flight anomalies with penalties assessed against members failing to comply with agreements. Organization of the proposed centralized space traffic control system is outlined in Figure 2.

Interchange of flight information would be simplified in a centralized control system. The state launching a space vehicle would furnish prelaunch information to the IAO-ANTACS Control Center, and postlaunch data would be substantiated by the tracking network and coordinated with the launching state (*e.g.*, in the event a decision was made to alter planned orbital parameters after launch in order to resolve technical difficulties). All prelaunch and postlaunch information would be

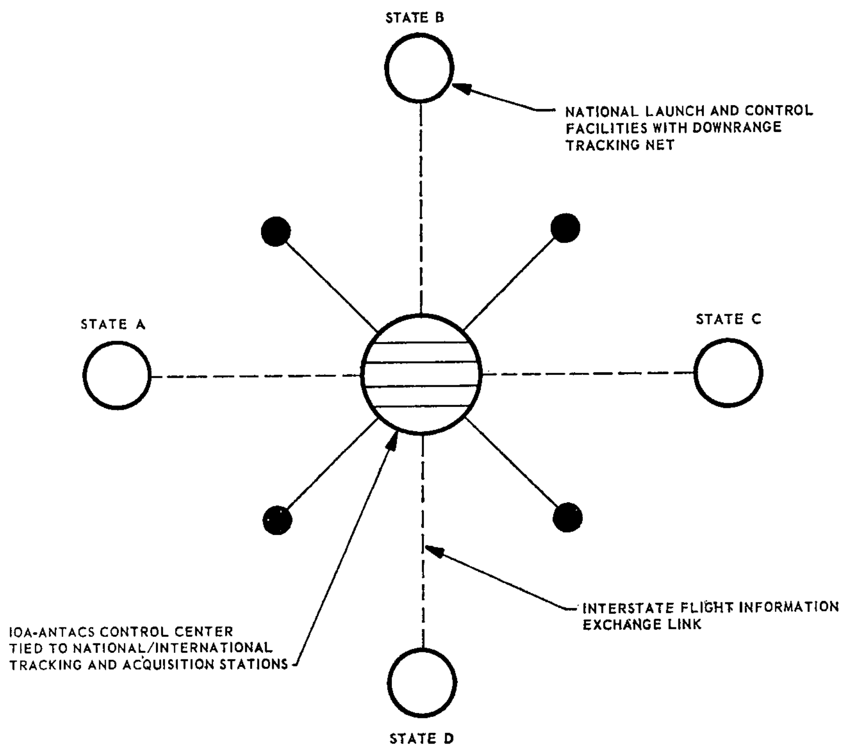

Fig. 2 A Centralized Space Traffic Control System

provided immediately to member states by the Control Center as it was received, and all states would remain continuously apprised of the existing flight patterns. If prelaunch or postlaunch data indicated conflict with flights in process, the conflicts would be reconciled between the Control Center and the state filing flight information before a collision condition developed.

The primary advantages of a centralized IAO-ANTACS are its low overall cost and improved operational efficiency. Cost for a system of this kind would be substantially lower than the combined costs of the redundant national ANTACS. Arrangements for sharing system costs may be developed whereby the major powers—which are the most active in space operations—assume a correspondingly larger portion of the financial burden based upon national gross national product or a similar equitable determinant.[20] Should a member state terminate its affiliation with the IAO

[20] *Cf.* Bulin, *Eurocontrol—A European Organization, Its Structure and Future Prospects,* 69 J. Royal Aeronautical Soc'y, 160-62 (1965), a reprint of the 9th Lecture given to the Air Law Group of the Society on 27 October 1964. Bulin summarizes the activity and structure of Eurocontrol, a new European organization devoted to the safety of military and civil air navigation in Europe. Included is a discussion of the method used for funding this international agency.

and refuse to supply flight data, the dislocation effect on the overall traffic control system would be minimized. Coordinated acquisition and tracking would facilitate the location and identification of unannounced flights. Moreover, the benefits to be gained by each state from safe navigation in outer space via membership in an IAO-ANTACS (*e.g.*, low cost of obtaining flight navigation data and efficiency of established operations) would temper hasty political decisions to withdraw and thereby lose them.

The principal disadvantage of an IAO-ANTACS involves the loss of national autonomic control over any significant portion of the centralized system. The determination of substantive issues by an international governing body of the IAO—requiring decisions arrived at by majority vote—would restrict the opportunity for an individual state to impose its policies upon the organization. (Vote weighting based upon the percentage of a state's financial contribution might be one method of ameliorating this situation in favor of the major powers.)

The compassing of a state's freedom of action in any field has never held much appeal for its leaders unless there has been no other reasonable alternative (as in the case of the International Telecommunications Union where the use of radio frequencies, for example, had to be standardized in order to prevent electronic chaos). The time is fast approaching when traffic control of space vehicles will also fall into this "no-alternative" category, for proliferating space traffic and the concomitant probability of collisions in the near-earth regions will make formation of an IAO-type organization[21] a practical necessity, not just a theoretical possibility.

C. *Some Corollary Conclusions*

The preceding examination of possible methods for organizing a universal space traffic control system was not predicated upon existing rules for navigation in outer space. Rather, adoption of an IAO-ANTACS is proposed as a necessary step toward guaranteeing safe space navigation in the absence of a spacecraft navigation code. Concurrent investigations leading to a uniform code for space navigation, perhaps drawing from the Maritime Rules of the Road, must also be undertaken in the development of space traffic control.

There are additional suggestions which may be made for enhancing the safety of space flight and for facilitating traffic control of space vehicles. For example, rapid spacecraft identification could be achieved through supplemental agreements to utilize special transponders or beacons for vehicles of each nation. Advances in the state-of-the-art and the international responsibilities involved in space exploration should occasion na-

[21] There remain several alternatives for establishing administrative jurisdiction; *i.e.*, whether responsibility over space vehicles in the atmosphere should reside with the International Civil Aviation Organization or with an IAO, or whether some sort of combined ICAO-IAO operation should be allowed to handle both aircraft and spacecraft traffic at all times in both areas of movement. Serious consideration of these alternatives must await concrete international discourse aimed at delimiting the zones for airspace and outer space, and at establishing traffic control of space vehicle flight operations. *Cf.* remarks on ICAO jurisdiction over spacecraft by Hassan Safavi, *The Problem of Applying Terrestrial Law in Outer Space*, Proceedings of the Fourth Colloquium on the Law of Outer Space 136-37 (1963).

tional efforts to alleviate some of the worst excesses of space cluttering.[22] Formal channels should be established for exchanging data collected on the physical space environment that directly relate to spacecraft navigation, such as radiation and micrometeorite hazards.[23] Standardization of procedures to follow in the event of a disaster in outer space—" 'the rescue of persons in distress' and [efforts] to 'render assistance to the other ship, her crew and passengers . . .' "[24]—should be studied and adopted. In addition, regulations requiring termination of electronic transmissions from space vehicles after their useful life is ended should be enforced strictly to avoid unwanted radio frequency interference with expanding earth and space services.[25]

In time, the subject of traffic control of space vehicles will be investigated more thoroughly, and further and more adequate recommendations for control can be expected. However, the time to study traffic regulation cannot be safely left to man's discretion. As nations continue to launch ever-increasing numbers of space vehicles into orbit and beyond—a condition reminiscent of the rapid expansion of air traffic in the second quarter of the twentieth century— some manner of traffic control will be required.

[22] Regardless of the final form traffic control assumes in the future, in order to create an environment in which safe navigation can be maintained, states participating in the exploration of outer space must eventually ensure that nothing is placed in orbit that cannot be deorbited, guided into the sun, or otherwise removed from all traffic patterns.

[23] McDougal, Lasswell & Vlasic, *op. cit. supra* note 13, at 514.

[24] *Id.* at 589, citing the Convention on the High Seas, Art. 12.

[25] This requirement has been in effect for all United States space vehicles since late 1961 by Executive Order. It was later adopted by the International Telecommunications Union in convention: Final Acts of the Extraordinary Administrative Radio Conference, Section 9, "Space Services," under "Cessation of Emissions," Geneva, 1963. With a few exceptions, this regulation has been observed by the Soviet Union and the United States.

TABLE 1

Prelaunch Registration

Filing of Registration and Identification Papers

1. Flag State ownership papers; certification of vehicle fitness
2. Public or private craft
3. Spacecraft identification markings and characteristics; weight and physical dimensions, including engine thrust, electrical power system, and type of booster launch combination, etc.
4. Manned or unmanned, certification of competent crew
5. Purpose of mission (scientific, civil, or military), and payload cargo
6. Electronic frequencies utilized for communications and navigation (presently standardized in the 1963 Geneva agreements reached by the International Telecommunications Union)

Filing of Flight Plan

1. Launch location
2. Planned launch date, time, and trajectory
   a. Hazardous air and surface launch and impact areas
3. Planned orbital parameters, including criteria for:
   a. Single or multiple objects on orbit
   b. Rendezvous and docking
   c. Orbital manueverability—planned times for changing orbits and planned parameters for new orbits
   d. Deep-space trajectory, orbital parameters around other celestial bodies, etc.
4. Planned lifetime on orbit/in space
   a. Lifetime-to-shutdown of radio transmissions
5. Planned reentry and recovery
   a. Vehicle and/or payload(s)
   b. Reentry trajectory
   c. Area and time
6. Planned disposition of booster vehicles, payload(s), and payload material (*e.g.*, copper needles experiments)—(guided into the sun, reenter to recovery, remain in orbit, etc.)

TABLE 2

POSTLAUNCH DATA

Redetermination Of Flight Plan Data

1. Actual launch date, time, and trajectory
   a. Hazardous air and surface launch and impact areas
2. Actual or reprojected orbital parameters, including criteria for:
   a. Single or multiple objects on orbit
   b. Rendezvous and docking
   c. Orbital maneuverability—planned times for changing orbit and planned parameters for new orbits
   d. Deep-space trajectory, orbital parameters around other celestial bodies, etc.
3. Actual or reprojected lifetime on orbit/in space
   a. Lifetime-to-shutdown of radio transmissions
4. Actual or reprojected reentry and recovery
   a. Vehicle and/or payload(s)
   b. Reentry trajectory
   c. Area and time
5. Actual or reprojected final disposition of booster vehicles, payload(s), and payload material (*e.g.*, copper needles experiments)