Session E :-

SPACE AND AVIATION

Lecture No. 13

Chairman: Prof. I. Neuman,
Head Meteorolog. Dept.,
Hebrew University,
Jerusalem.

CONTRIBUTIONS OF THE SPACE PROGRAMME TO AVIATION

H. Cohen

Director Reliability, Quality & Safety -
Apollo project, National Aeronautics and
Space Administration, Washington.

Annual Symposium

National Council for Civil Aviation

Tel Aviv - Israel

October 8-9, 1969

NASA and its predecessor NACA have been contributing directly) air transport safety since its inception in March 1915. Experimentation on ietal fatigue, fire protection, crash survival, aircraft handling qualities, tability and control systems, friction of runway surfaces are just a few of the reas involved. This paper, however, is not aimed at these direct areas of upport, but rather to the indirect areas or spin-offs which have come from ASA's space activities and will be of assistance to air transport safety.

Most obvious of all the spin-offs are the ones associated with the se of satellites for navigation, for weather prognosis, for communications and n the future, air traffic control. Let's look at these satellites in a bit more etail. First, the meteorological satellites. These started from simple xperimenting with earth photography back in the 1940's and now blossomed nto operational satellites which provide daily pictures of the earth's cloud over and infrared observations. These data are used routinely in improving me-day to two-day weather forecasts. Such weather pictures are given to ransatlantic pilots to show them the weather to be encountered enroute. They iave been used to save ships at sea by directing them out of the midst of storms into good weather conditions and to manage field operations in construction and agriculture. They have made possible more accurate hurricane and storm warnings, with the resulting saving of lives and valuable property. The current operational meteorological satellites, named ESSA for the environmental science services administration, stem from NASA's TIROS (Television Infrared Observational Satellite) research and development satellites. Now, to lay the groundwork for even more valuable meteorological applications, the Nimbus Satellites in polar orbits of about 600 miles altitude, and applications technology satellites (ATS) in synchronous equatorial orbits at 22,300 miles altitude are being used for advanced research and development. A recent breakthrough on the Nimbus III Satellite, in which it was shown to be possible to obtain temperature profiles of the earth's atmosphere from satellite-borne instruments, gives encouragement to those who look forward to the day when a global meteorological satellite system will make long-range weather forecasting possible. The application technology satellites in synchronous orbit have shown that it is possible to keep watch on the development of hurricanes, typhoons, thunderstorms, tornado weather, and the whole range of weather conditions from large-scale long-term to small-scale short-term. The importance of this capability to improve weather forecasting is inestimable, but the ultimate value to agriculture, aviation, transportation in general, commerce, construction, etc., has been put at billions of dollars annually.

Intelsat Communications Satellites in synchronous earth orbit now provide point-to-point communications services from continent to continent. Using them, major occurrences of international significance, such as political events, the recent Apollo 11 lunar landing mission, and sports competitions, can be seen around the world while they are actually happening. These communications satellites grew out of a wide range of satellite experiments, including those with Telstar, relay, syncom, and the large echo balloon satellites which, looking like a bright moving star, have been seen by millions of people around the world. The Intelsat spacecraft are bought and operated by the Communications Satellite Corporation, for which NASA provides launching services. The Comsat Corporation is the chosen manager for an international consortium consisting of 68 countries. At the present time 17 countries have 26 ground stations in operation with the satellite system. By early 1970, 45 ground stations should have been installed around the world to operate in a total of 31 countries with the satellite portion of the network and to interface with the ground-based communications lines that are necessary to complete the total net.

The navy has developed and is using a navigation satellite system. NASA has been doing research on how such a satellite navigation capability may be made available to aircraft and private marine interests, including the very small user. For all these purposes, the user's equipment must be small, lightweight, and inexpensive. Of particular importance in this connection is the matter of air traffic control As you people so very well know, the problem in this area increases as traffic congestion grows day by day. NASA has been experimenting with its communications and applications technology satellites on continuous communications with transcontinental and transoceanic aircraft. The ATS-E Satellite, recently launched into synchronous orbit, 22,300 miles above the equator, is carrying L-band communications and air traffic control experiments. This frequency assignment has more capacity and is less crowded that the VHF spectrum tested on earlier satellites. It is now being tested as an aid to communications and position determination of aircraft. The results will be compared with those previously obtained at VHF which showed that aircraft could be contacted by voice and teletype and that the position of the aircraft could be established for navigation purposes. Those experiments also established the fact that photocopies of cloud cover taken by meteorological satellites could be transmitted directly to pilots to give them up-to-date weather information. It is true that the uncrowded UHF band would require new equipment on aircraft but this frequency band has 1550 channels while VHF has only 137. This experiment is applicable around the world and a number of countries are participating. Data returned by ATS-E is being used in the design of the ATS-F Satellite, and eventually we expect that an improved model of the satellite could be capable of showing ground controllers precisely where every plane is at any moment. This could lead to a system where ground control would have no need to query aircraft except in the event of a system failure. It is also conceivable that downed transports could be quickly found with suitable transponder devices monitored by satellites in contrast to the passenger DC-3 that crashed in the Rocky Mountains last winter and was not found until July.

An additional area, associated with the communication field, is the accident investigation field. Sophisticated flight recorders, crash and fire proofed, or telemetry, can contribute enormously to the rapid solving of the accident investigation problem. A good example is the DC8 fatal training accident involving a two-engine-out approach. The on-board flight recorder enabled the probable cause to be determined in a few weeks, whereas, without sophisticated flight recorders the average time to arrive at a probable cause in fatal airline accidents is eleven months in the United States. Objections to widespread use of telemetry and recorders are well-known - what will be done with the vast amount of data these devices can collect? Solutions are equally well-known - discard that which has no value. The extensive use of telemetry by NASA through its associated world-wide networks of tracking stations offer a tremendous potential for monitoring the operational performance of high speed long range aircraft. In the event of an accident it will provide data to determine rapidly the probable causes. As previously mentioned, telemetered data could be limited to that which exceeds "red line" values and to other anomalies. The economic advantage of shortening the accident investigation, reducing guesswork and expensive accident research to effect a fix can be enormous. The costs of telemetry should be balanced against the enormous costs incurred when an airplane model has to be grounded or its performance curtailed pending determination of the cause of an accident.

Some examples of NASA's investigations of anomalies and structural failures illustrate what has been done in space operations that should be of value in air transportation. The flight of Apollo 6 of April 4, 1968, had two engines shut down in flight; another failed to restart; unacceptable longitudinal vibration called "POGO" took place; and a panel of metal measuring about 36 square feet was lost from the adapter section surrounding the lunar module. The engine failures were caused by the rupture of a flexible propellant connection and the partial failure of another. An oversight in the installation and testing of a section of electrical wiring caused one of the engines to shut down. The loss of the metal panel resulted from a unique combination of vertical and longitudinal oscillation.

This occurred hundreds of miles in space. The parts were never seen or examined again. Yet the reasons for their failure were determined, verified and fixes tested within eight weeks. The basic data was obtained by telemetry from temperature probes and accelerometers. The techniques used for this analysis are being published by NASA. Hopefully they will arouse interest to accelerate the determination of causes of large air transport accidents of the future.

Even with these anomalies the vehicle went into orbit for which there was a contingency plan of operation. The astronauts, had they been onboard, could have completed the mission safely. This is a remarkable confirmation of the nature of the engineering effort for space operations that can be useful to aviation.

An inertial guidance system derived from that which carried Apollo 11 to the moon is now being installed in the Boeing 747. Guidance and control equipment recovered from the Gemini XI spacecraft is being flight tested aboard a helicopter by NASA. This includes the computer which controlled the Gemini XI descent, the inertial navigational system and the power supply. The purpose of this test is to help develop the system performance requirements for automatic landings for future VTOL and STOL aircraft. The radar approach system developed for the Gemini program is being evaluated at Wallops Island for use on aircraft for all weather landings.

Development in the monitoring of the physical condition of the astronauts will lead to very simple unobstrusive devices not attached to the body which will warn the pilot of fatigue or inattention as well as impending illness or perhaps a heart attack.

Space offers unique conditions that suggest that certain kinds of manufacturing should be carried out in space stations. The weightlessness and vacuum environment could be used to produce new materials or products made more precisely. For example, liquid floating in a weightless environment, takes the shape of a perfect sphere. Thus, it is conceivable that metal ball bearings could be manufactured in space to tolerances impossible on earth, yet at a cost, including transportation, less than we can now achieve. Such perfect bearings would reduce friction and noise levels to the vanishing point. A possible application would be in jet aircraft engines. Stable foams for mixtures of liquified materials and gases offer exciting possibilities. Such foams cannot be satisfactorally produced on earth. In weightlessness, the mixing and equal distribution of gas bubbles in any liquid can be stabilized and moved into a desired pattern. Using this technique, we can produce a steel foam almost as light as balsa wood with many of the properties of solid steel.

Of even more importance, composite materials like steel and glass of drastically different densities and properties can also be produced. Some potential applications of these foam materials are extremely lightweight construction components, variable density turbine blades and versatile insulating composites to withstand extreme temperatures.

Recently NASA established at the Lewis Research Center, the Aerospace Safety Data and Research Center. It is intended that this Center will serve two major purposes - the first to actively collect and disseminate (via computers) information on aerospace safety. The data will either be directly available or information will be supplied on where the information may be available from similar centers established by industry or other government agencies. The ASDRC will evaluate information received, suggest names of knowledgeable specialists in particular areas, and recommend research projects. The second major task will be to carry out basic safety research where needs have been identified. The first of these research programs has recently been initiated in the area of basic fire research. Plans are being laid to explore new techniques in early fire detection, in fire extinguishment and in particular, attacking the difficult problem of hypergolic propellant fires. This effort is under the direction of a Spacecraft Fire Hazards Steering Committee made up of selected leaders in safety, materials, spacecraft design, flight operations and has members from the Department of Defense and from the Federal Aviation Agency. The Committee is concentrating on selecting appropriate fire detection techniques applicable to the orbital workshop to be launched in 1972 as part of the Apollo Applications Program. Some of the techniques being considered could be of considerable interest to the aviation world. It should be noted that each technique being explored has some discrete limitations and the current thought is that at least two separate techniques should be used in an "AND" logic circuit before a fire alarm signal would be generated. I will briefly discuss two of the more promising approaches.

Condensation Nuclei Counters

Condensation nuclei are submicroscopic airborne particles, either liquid or solid, ranging in size from 0.001 to 0.1 micron in diameter.

They originate generally from combustion or from photolysis of gases. These airborne particles or nuclei are smaller than the wavelengths of visible light and are too minute to be seen, even with high power optical microscopes. To detect these nuclei optically, it is necessary that they be enlarged. This is accomplished by condensing water vapor upon the nuclei, causing them to grow into water droplets of about five microns diameter. Condensation is achieved by creating a condition of supersaturation of water vapor within an air sample. If particles are present in the sample, they act as nuclei or centers about which condensation proceeds. If no particles are present, condensation will not occur for supersaturations up to several hundred percent. In the diagram illustrated, an air sample is drawn into the instrument, humidified and carried to an expansion chamber. A rotary disk valve controls the flow of the air sample in and out of the chamber. While in the expansion chamber, the air sample is subjected to adiabatic expansion, causing a sudden drop in temperature and resulting in supersaturation of the air sample. Condensation proceeds rapidly about any particles present and, in a matter of milliseconds, visible water droplets are formed.

As these water droplets grow in size, the degree of density of this cloud varies the amount of light impinging upon a light-sensitive cell, providing a measurement of the nuclei present. The produced electrical signal is processed electronically to an output meter to provide an essentially continuous, real-time indication of particle concentrate. The sampling process can be repeated at a rate as rapid as 10 times a second. A typical commercially available device (not packaged for space application) is 5x7x3 inches, weighs $3^1/2$ pounds, uses 4.4 watts of 24 VDC power, has a dynamic range of 500 to $5\text{x}10^5$ particles/cc, has a sample rate of 2 per second and uses an input air flow rate of 20 cc/second.

Some key factors being explored in use of this instrument are:

1. Sample flow rate is low compared to spacecraft volume. Needs multiple sampling tubes and manifolds from scattered areas to provide broad coverage. In long tubes, nuclei could be lost by plating out on walls of tube.

2. Will all combustible spacecraft materials produce nuclei when heated or burned?

3. Is the temperature at which nuclei are produced sufficiently lower than the ignition temperature of a material so that overheat can be detected before a fire starts?

4. Will the spacecraft environmental control system remove nuclei and thus prevent a detection?

5. Can nuclei be generated by a non-hazardous situation, such as the controlled heating of some unit which has been contaminated (e.g., Ethylene glycol spill)?

6. Will nuclei be generated by heated material under zero gravity and convection free conditions?

Best approach seems to be:

1. Use this device as a backup overheat and fire detector in two ways: one, a fixed installation with a sampling port at the entrance to the environmental control system and the other a handheld portable unit to find the point source.

2. Explore the possibility of enhancing the generation of nuclei in potentially hazardous areas by the use of some type of coating or "doping".

Continuous Wire Fire Detection System

This technique is certainly familiar to this audience, since versions of it have been used for many years on all types of commercial and military aircraft. It consists of a continuous sensing element made up of an inconel tube sheath containing a ceramic-like thermistor material in which are embedded two electrical conductors. The thermistor changes its electrical resistance between the conductors with temperature at normal ambient temperatures, resistance is high, dropping rapidly as the sensor is heated. A control unit, using a simple transistorized bridge and trigger circuit switches on the alarm when the resistance of the sensor drops to the pre-set level. When the fire or overheat condition has been eliminated, the sensor resistance rises again, the control unit resets automatically and is immediately available for further detecting duty. Normally the sensing elements are connected in a loop with each end of the loop connected to the control unit, thus, should a break occur, the control unit continues to monitor the sensing element from each end to each side of the break and thus continues to function normally as a fire detector. For increased reliability, this sensing element is available in an armored, redundant form, including dual control units with redundant control circuits in one envelope. Control circuits are protected by a zener diode regulator so that voltage transients as high as 1000 volts are shunted without a flicker of the fire signal.

Operating on the difference in rate of resistance change, the short discriminator circuit discriminates between a lowered resistance caused by a fire and a lowered resistance due to a short circuit.

The circuit will also not trip in the presence of soluable salts which, in presence of moisture, would form an electrolyte. This is because the circuit operates at approximately 0.5 volts DC which is well below the polarization potential of the electrolyte.

It is possible to have a combination of overheat and fire two-stage alarm or a rate of temperature rise alarm.

Key factors in consideration of this device are:

1. Commercially available with lots of performance history.
2. Detector is small, light in weight, rugged, small in power consumption.
3. Can be incorporated directly in wire bundles, routed through electronic components and other heat sources.
4. Location of high temperature regions in long continuous loops can be determined.

Known disadvantages are:

1. Although a detector can be designed for any reasonable normal ambient temperature, this "normal ambient temperature" must be known for all detector locations for all normal operating conditions if failures to alarm and false alarms are to be avoided.

2. Physical size of sensor is small compared to size of a spacecraft. To respond, heat must be transferred to the detector by conduction, convection and radiation. The time to transfer enough heat to the detector element may be excessive unless the distance between heat source and detector is small. Thus potential fire hazard areas must be determined and detectors placed as close as possible.

The best approach to date seems to be to use this system as a primary system in conjunction ("AND" Gate) with the previously discussed condensation nuclei device.

The spacecraft fire hazards steering committee has also examined the applicability of a correlation spectrometer device and has discarded it because of its very early stage of development. It will be monitored for possible future applications. Future tasks of the committee are to explore the use of ultraviolet and infrared detectors, investigate and consider the use of temperature sensitive crayons or paints (color change) as an auxiliary overheat detection technique, explore the use of tracer materials to enhance the performance of the condensation nuclei counter and finally to evaluate the order of magnitude of the sampling problem and the time response of the condensation nuclei counter and the continuous wire detector in a typical spacecraft situation.

The utilization of system safety analysis techniques, used to a great extent on the Apollo program by the Boeing Co. in its technical integration and evaluation role (tie contract) has also been used by them on the Boeing 747 aircraft. The specific technique is a computerized functional logic analysis called "fault tree analysis".

NASA requires system safety by contractual obligation, i.e. funds are allocated to the conduct of systems safety. This means that top management must concern itself with the safety per se. This top mangement attention are focused at key milestones in the development of a program. These milestones are labelled preliminary requirements review, preliminary design review, critical design review, the signing of a certificate of flight worthiness, design certification review, and flight readiness review. I am sure that airlines also have technical reviews of their coming development flights but I wonder how many of these are attended by vice-presidents or presidents of the companies?

NASA has carried out extensive research in the area of non-combustible materials and has developed substitute, acceptable materials which are non-flammable and produce minimum toxic outgassing products when exposed to reduced ambient pressures. A very careful accounting of all materials tests which have been performed have been entered into a computerized program called "COMAT" for compatibility of materials. This information should have direct application to air transports. The airlines have suffered several very expensive fires due to electrical wiring which gutted aircraft on the ground. NASA has learned the hard way that the cost of going to expensive means to prevent fires is justified. I might add that the air transport industry is face with risks of great magnitude also. It is estimated that the loss of a fully loaded 747 could cost $84 million as against $35 million for a fully loaded DC-8. The research on materials may not be totally applicable because NASA had to provide protection in a 100% oxygen atmosphere which the airlines do not yet face. However, even in a mixed atmosphere, use of available substitute, low or no burning rate materials can drastically reduce flame propogation rates. Certainly, when the airlines operate a space shuttle type of aircraft from Tel Aviv to New York in about 30 minutes, the full requirements now applicable to spacecraft materials may be thrust upon them.

NASA has confirmed the use of simulators for training without recourse to the actual vehicle. The best example perhaps is the lunar landing training vehicle. In this device, using a jet engine to simulate the 1/6 "G" of the moon, Apollo astronauts trained on the intricacies of the final descent and landing on the lunar surface. This device, affectionately called the "Flying Bedstead" provided a realistic and valuable training aid as reported by the Apollo II astronauts. This area is of much current economic interest to the airlines. However, I would not rule out some final boning up in the aircraft you use before you carry passengers.

The development of systems for waste management will probably be of interest to airlines using large capacity airplanes. Although the early space station designs are designing waste management systems which allow the return of urine and fecal matter to earth for medical analysis, later versions of the space station will provide means for drying and probably burning waste material produced during extended periods in space.

Miniaturized television or "Wee TV" has immediate applicability for aircraft use in the inspection of inaccessible areas. They can be made small enough to inspect the inside of the stomach.

New X-ray techniques, improved by electronic image intensification and coupled to computers can produce information and inspection results heretofore unavailable.

NASA has encouraged studies and research to improve quality assurance techniques. This includes criteria for the selection of inspectors, the measurement of inspector performance, improvements in tools used by inspectors and the manner of conducting experiments. One such study is "human factors in quality assurance" published by the autonetics division of North American Rockwell.

The development of the space shuttle vehicle will be of inestimable value in design of future aircraft. Consequently, I would like to spend the remaining few minutes in reviewing our plans and concepts leading to operational use of such a vehicle.

Space activity has been constrained by the high cost of putting things into orbit, and their inaccessability once they are in space. For example, our studies have shown that the cost of a large space station would be less than 30 percent of the total operating costs, including logistics support using existing space transportation systems. This brings us, therefore, to the development of a low cost, reusable space shuttle.

Study contracts are now in effect which should, before the end of the year, result in our being able to move forward in a decisive fashion toward the design and development of this vehicle. It is expected that the space shuttle will provide a transportation capability to and from earth orbit at costs more than an order of magnitude lower than are now being achieved.

For a very large reduction in costs, it is apparent that the essential feature needed is vehicle reusability with low cost maintenance analogous to current aircraft techniques. With the use of appropriate system design and high performance technology, it appears feasible at reasonable cost to undertake development of an earth orbit shuttle system. Such a system, for use in 1976 and beyond, would rotate crews and carry large discretionary payloads, perhaps as much as 25,000 to 50,000 pounds.

Such a vehicle, possessing the potential for reducing the incremental cost of transportation to orbit to about fifty dollars or possibly lower per pound of payload, would have an enormous effect on the evolution of the space program. Consequently, initiation of work in all areas necessary to achieve a low-cost transportation system is being given high priority.

Designs for such a system are now being generated throughout the world. One concept consists of a stage and a half to orbit, using disposable fuel tanks. In addition, some interesting new designs are evolving in which all major equipment is reusable.

One such concept has two boost elements and one orbital element which conjoin in a parallel arrangement for vertical launch. All three of the elements are aerodynamically similar and have identical basic structures and propulsion systems. The engines in the orbital section would draw propellant from the booster sections up to staging velocity. Then, the two booster elements having exhausted their contents and been staged off, the center element would continue to accelerate to orbital velocity.

The two staged elements would make gliding entries and then extend wings and proceed to the landing area under the power of turbofan engines at subsonic speed. They could travel about 300 miles to a predetermined landing area, or curise back to the launch site.

The orbital vehicle would go into orbit, deliver and pick up cargo, and return to earth, deploying wings after entering the atmosphere. It would land with turbofan engines.

This concept is fully reusable and all elements are fully controllable. It could be launched overland in any direction for an ideal trajectory and it could execute a powered landing much like that of a conventional subsonic aircraft. In case of a missed approach, each of the three sections of the vehicle could perform a go-around maneuver.

Another promising concept under study is essentially a "piggy back" design in which a large propellant-carrying winged vehicle would supply the necessary boost to inject a smaller orbital vehicle into earth orbit. The carrier would be able to return to earth under the power of turbofans, and the orbital vehicle, also winged, would carry enough fuel for orbital operation, and would also return to earth for a controlled landing again with turbofan engines.

An attractive characteristic of all space shuttle concepts is that while they travel at extreme speeds, they do not create a sonic boom. There is of course, the roar of lift-off, but entry into the atmosphere takes place at about 400,000 feet, and sound and speed are greatly reduced before the craft comes in for a landing.

This is only one of the factors which makes these designs of great interest to many in the aviation community who see it as the progenitor of transport aircraft for global operations.

A great many new technologies will, of necessity, be developed to make the space shuttle operational. Principal among them will be either a repetitively useful, or an economically refurbishable heat shield. The present state of the art indicates that one or both of these methods will be available. Engines are already under development which are expected to be operational within the required time.

In order to achieve optimum results in the space vehicles I have described, some new thinking in the areas of check-out and control will be essential. The developments which we foresee might result in a considerable step forward, not only in the design of this kind of space vehicle, but also in conventional aircraft as well.

As we have learned to build more sophisticated circuits and design more complicated spacecraft, we find that there are more and more cables that go from point to point around and throughout the vehicle. The cables begin to weigh almost as much as the components they connect, and they also generate most of our problems. A decade or two ago a five prong connector was a fairly complex thing. It was a great breakthrough when we had an eight prong connector. Now 800 little wires come out of the bottom end of a connector because every designer wants to be sure that everything is going in that could possibly go in, and that everything is coming out that could possibly come out.

I think we have an opportunity at this point to make a real breakthrough. I think that there should be no more than five wires going into any black box that we design - one connector with five wires in it.

One or more of those wires might be coaxial, but it would be designed as a single connector. Those five wires would have the following functions: The first one would be a wire that gives three pieces of information about the box, (1) "I am well, I am ready to go". (2) "I am sick and I cannot help you", and (3) "I am about to get sick". That is all the information we would need about that black box.

The second wire would carry all the inputs that the black box gets from the outside world.

The third wire would carry the output - all of the signals coming out of the box.

Two more wires would be for the power supply which would be uniform as would the power level. The black box would do the rest. The power would be conditioned internally.

A design of this sort would not have been possible five years ago with any degree of dependability, but in the last five years there have been some relatively significant improvements in our ability to build reliable electronic circuits in very small volumes. The advent of large-scale integrated circuits will make it possible to build into each black box sufficient redundancy and sufficient logic, so that all of the points which should be measured can in fact be measured, and can be measured with triple redundant instruments. The logic circuits can provide the kind of information needed for the box to report that it is about to get sick and that in about 20 or 30 hours something would have to be done about it.

Taking advantage of circuit technology, redundancy can be introduced so that, at least in the logic circuitry and in many of the main circuits, triple modular redundancy on a proper system level could be used. The aim should be to have a black box that is not only highly reliable but fails gracefully and provides adequate warnings that it is going to fail at some future time.

Of course I am not just talking about electronic boxes; I regard an engine as a black box. There ought to be enough logic built into this engine so that the pilot knows in advance whether or not the engine is going to start. It should have its own internal set of controls and ought to be able to condition itself from the external supply without having any additional inter-connection and wires. The same "five-wire" principle ought to apply to the engine.

Since we are talking about building a new kind of transport system, the space shuttle, we should take advantage of the electronic possibilities which are now present, and build this new system properly from the start. I believe that we can surely design a central computer system to do the entire check-out of this vehicle. We should decentralize at this point. Let us move the complexity back down into a black box and let the designer face up to the problem of making sure that his black box is going to work. By moving the complexity into the black box, where it can be controlled, the system becomes simplified rather markedly.

Another area which needs to be rethought in connection with our new transport system is that of pilot displays, pilot controls and other furnishing of the cockpit. As the Apollo command and service module has grown, the originally clean interior surfaces have become so covered with dials and gauges that there is now no surface visible within the spacecraft.

There are so many switches that it has become extremely difficult to change the cabin configuration for a different mode of operation. It is a major chore just flipping switches in the right direction to change from launch to orbit or to any other configuration. One of the things that computers do extremely well is switch. They can also tell if the switch is where it ought to be and change it to a preprogrammed configuration.

The pilot would then be able to question the central computer concerning every part of the vehicle, and receive a report on each one. He would then dial in the preprogrammed configuration of the part of the mission which he required, and the computer would obey. In each case he would set in the appropriate program, and the computer would do the necessary work.

These may sound like idea concepts -- but I believe they are now possible. These improvements will come, and they will be hastened into existence by the needs of the space shuttle, which is so important to our continuing expedition into the new territory of space.

If we persevere, I believe that the space shuttle can be operational within 7 years. And within these 7 years many more of the nations of the world will have begun to express their aspiration in space activity. Even now, in addition to the United States, Russia, Great Britain and France, Italy, Japan and West Germany are already active in the space arena. Therefore a sufficient commercial market for the space shuttle might be in existence by the time the craft is ready to fly.

With a price tag of, say \$50 million each, a number of nations might be able to afford a space shuttle. Of course, no considered price can really be named because no really meaningful estimate of the number of space shuttles that will be needed can be made at this time. For that number is a function, not only of the various jobs it will be called upon to perform, but also of the existence of the system itself. After all, no one knew he needed a telephone, a computer, or an airplane before they existed.

This brief description of some of the products, results and future goals of our national space program only hints at its significance in the life of every man. It is too soon to tell what effects will be evident in our civilization in 10 or 20 years. Who in 1913, ten years after the invention of the airplane would have guessed the far reaching and myriad changes which that single concept brought about? We can guess, extrapolate, wonder, but our imaginations are taxed when we consider that the space program opens so many new avenues at the same time. We have the giant launch vehicles which will permit men to travel where they will, and we have made our first landing on a new world where no man had ventured.

The consequences of the synergistic effects of all of these elements are truly beyond our ability to forecast.

TYPICAL FUNCTIONAL DIAGRAM, CONDENSATION NUCLEI COUNTER

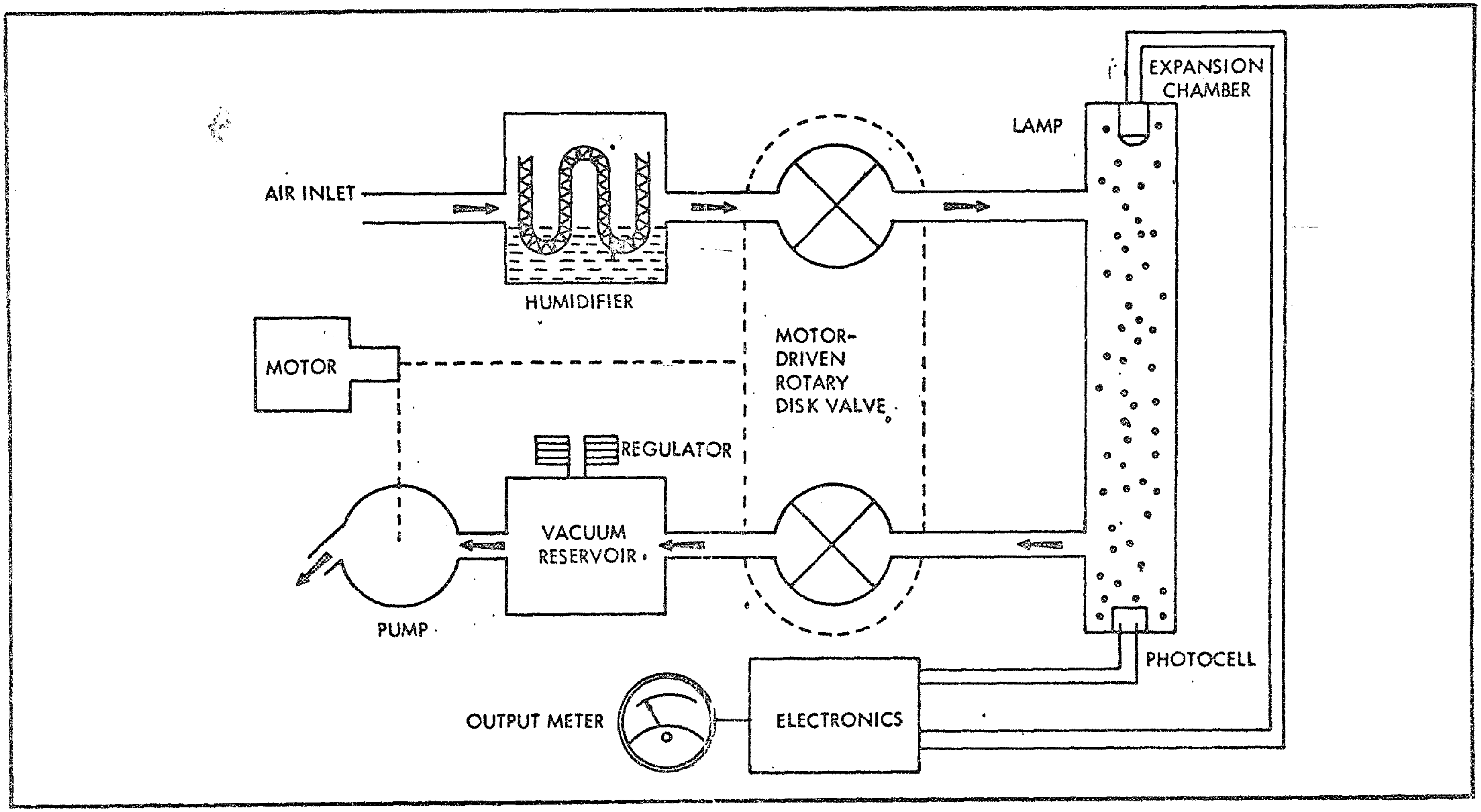

FIGURE 1

NASA HQ ML69-6249
9-30-69

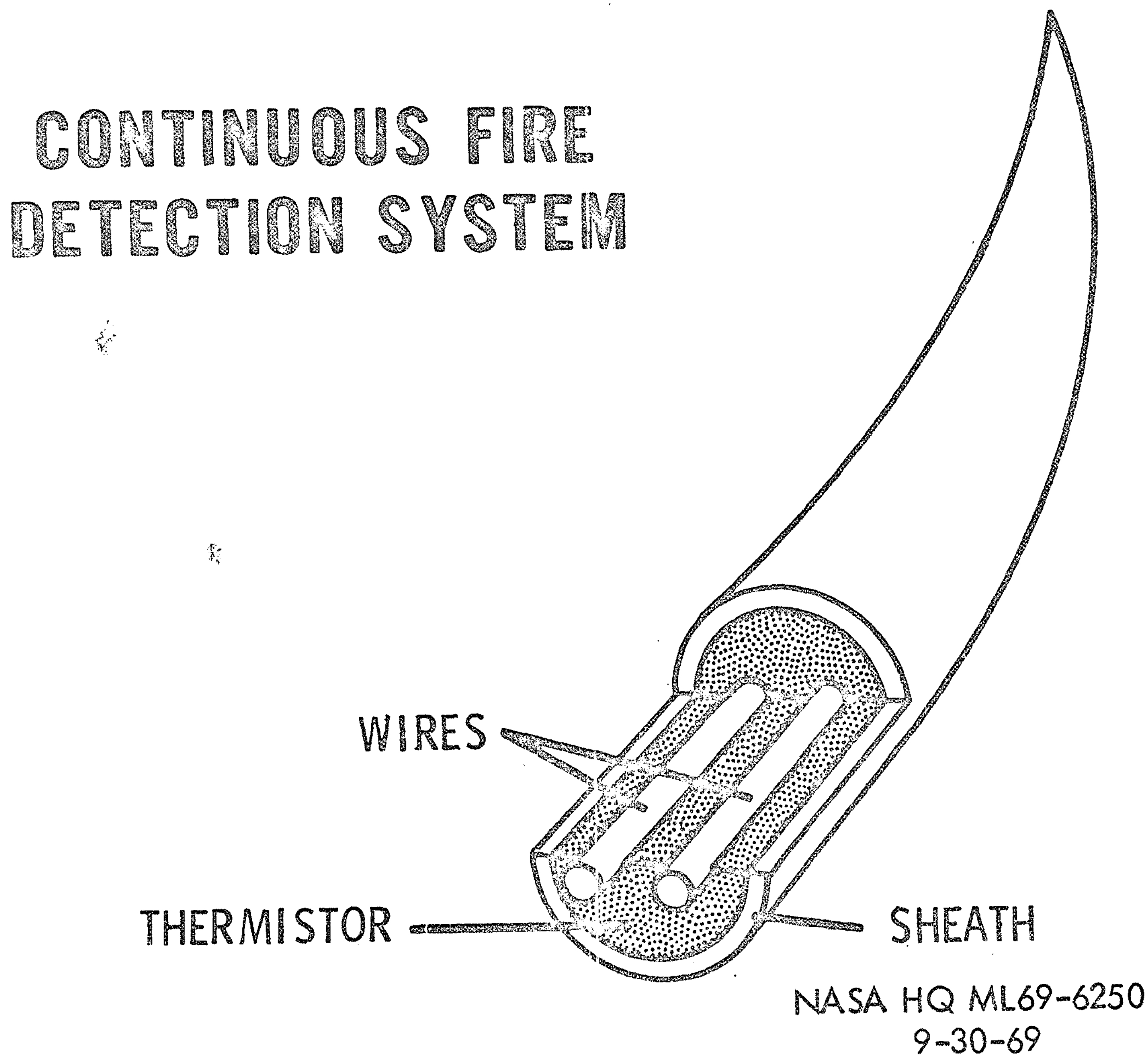
CONTINUOUS FIRE
DETECTION SYSTEM
WIRES
THERMISTOR
SHEATH
NASA HQ ML69-6250
9-30-69

FIGURE 2


TRIAMESE CONCEPT
UNITED STATES
UNITED STATES
UNITED STATES

FIGURE 3

TRIAMESE OPERATIONAL APPROACH

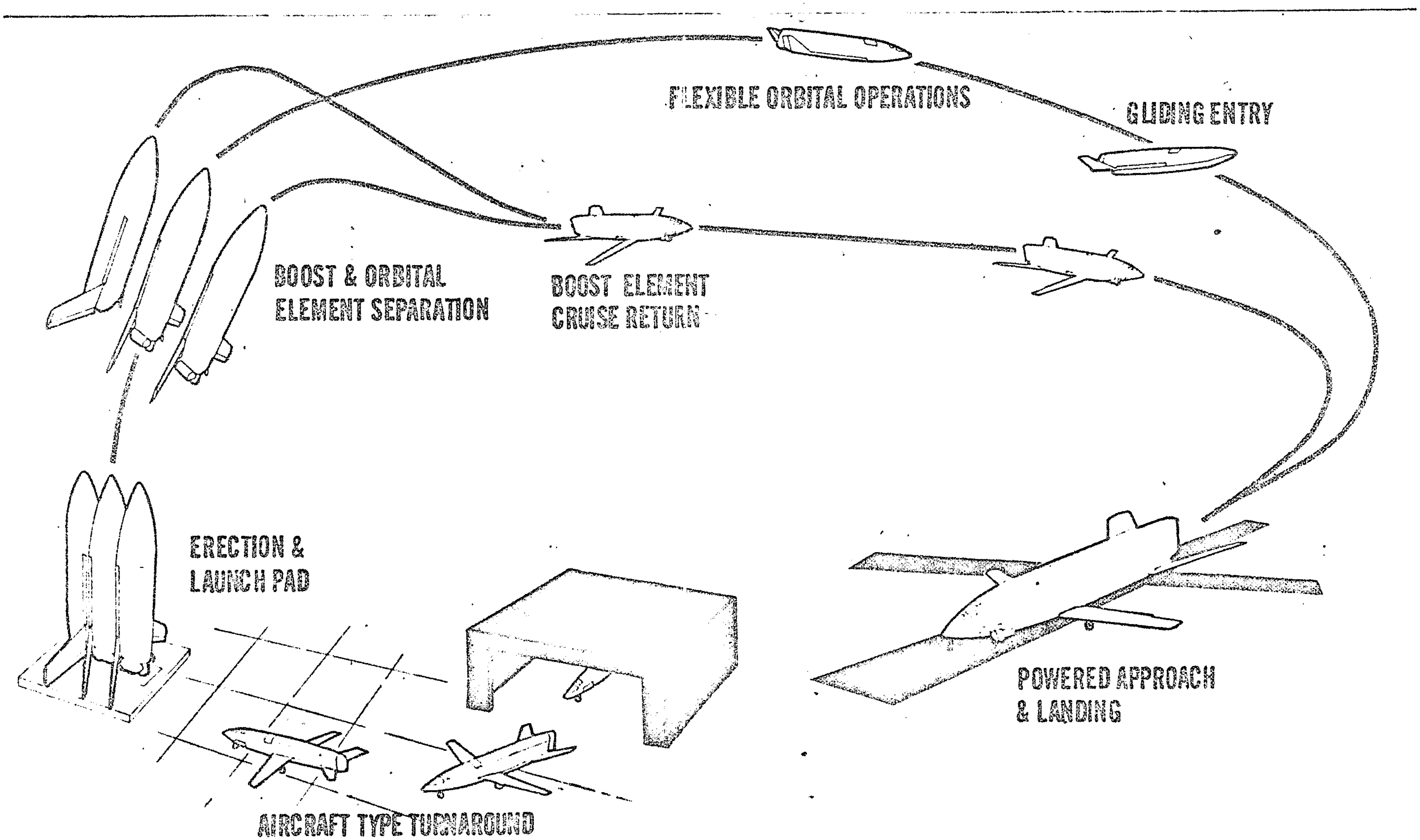

FIGURE 4

NASA HQ MT69-4551
3/7/69

The symposium was concluded by the address of Mr. Michaely, Director General of the National Council for Civil Aviation, who indicated the high level of the discussions and the ever increasing participation of aviation personnel.

He expressed his hope that the wish of those interested in aviation to have more symposia, which are an excellent source for first hand information, as well as an opportunity for an exchange of views, will, indeed, be fulfilled.

Mr. Michaely said he believed that the N.C. for C.A. will endeavour, with the assistance of the Ministry of Transport and Communications and the close cooperation of aviation enterprises in Israel, to continue the tradition of annual symposia on topical subjects in aviation development to the benefit of all concerned.