CENTERLINE LATCH TOOL FOR CONTINGENCY ORBITER DOOR CLOSURE

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ABSTRACT

The centerline latch tool was designed and developed as an EVA manual backup device for latching the Space Shuttle Orbiter's payload bay doors for reentry in case of a failure of the existing centerline latches to operate properly. The tool was designed to satisfy a wide variety of structural, mechanical, and EVA requirements. It provides a load path for forces on the payload bay doors during reentry. Since the tool would be used by an EVA crewmember, control, handgrips, operating forces, and procedures must be within the capabilities of a partially restrained, suited crewmember in a zero-gravity environment. The centerline latch tool was designed, developed, and tested at the Johnson Space Center to meet these requirements.

INTRODUCTION

The Space Shuttle Orbiter's payload bay doors are opened soon after entering orbit and remain open until just before reentry. The doors are opened/closed and latched sequentially, either manually from the on-board control panel or automatically from the on-board computer, by electromechanical actuators. A detailed description of the complex payload bay door system is discussed in a paper entitled "Space Shuttle Orbiter Payload Bay Door Mechanisms" (Ref. 1) given during the 13th Aerospace Mechanisms Symposium at Johnson Space Center, Houston, Texas.

The door mechanisms consist of four basic subelements: door drive actuation, forward bulkhead latches, aft bulkhead latches, and centerline latches (Fig. 1). The door drive system moves the doors to a designated position by two actuator systems, one on either side of the payload bay. Each system drives one 18.3-meter (60-foot) door and consists of an electromechanical actuator that drives six gear boxes interconnected by torque tubes. Each gear box then rotates the drive linkage to the door. The forward bulkhead latches connect the doors to the forward structural bulkhead. These latches consist of a right-hand gang of four latches and a left-hand gang of four latches that operate sequentially. The active latch mechanism is mounted on the door, and the mating passive hook rollers are mounted on the bulkhead. Each gang of latches is driven by a single electromechanical rotary actuator with two motors. In the same manner, the aft bulkhead latches operate and connect the doors to the aft structural bulkhead. Finally, the centerline latches connect the right-hand and left-hand doors along the centerline. There are four gangs of latches (four latches per gang). The active latch mechanisms are on the right-hand door and the passive mating rollers are on the left-hand door. The four latches within each gang are connected by torque tubes to each other and to a single electromechanical rotary actuator. The centerline latch system is shown on Fig. 2 and 3.

A failure in any of the four basic door mechanisms could require a manual EVA operation using one or more specially designed Orbiter door closure tools. These tools would disconnect a disabled door or latch system and close and secure the doors if the normal system failed. The set of EVA Orbiter door closure tools consists of a tubing cutter, a winch, a 3-point latch tool, and a centerline latch tool. The tubing cutter, the winch, and the 3-point latch tool have been previously discussed in detail in a paper entitled "Orbiter Door Closure Tools" (Ref. 2) given during the 14th Aerospace Mechanisms Symposium at NASA Langley Research Center, Hampton, Virginia.

The basic types of potential failures, their causes, and the required EVA actions are described in Table 1. For a door drive system failure such that the door can neither be opened or closed, the EVA crewmember uses the tubing cutter to cut the upper or lower drive tubes. Once the door drive tubes have been cut, the EVA winch rope hook is routed over the number 4 bulkhead hook roller and attached to the number 4 latch bellcrank at the tip of the door. The rope is then reeled back in by the winch until the door has been fully closed. If a gang of bulkhead latches on either end of one or both doors fails to operate properly, the EVA crewmember uses the 3-point latch tool to fully close and secure the door.

CENTERLINE LATCH TOOL

If a gang of centerline latches on the right-hand payload bay door fails to operate properly, the doors must be safely secured by some other means. The centerline latch tool is an EVA manual backup device for latching the Orbiter's payload bay doors for reentry. Four of these tools (enough to bypass one gang of latches) are carried onboard the Orbiter.

Design criteria required that the tool fit all 16 centerline latches. It had to be able to interface with the existing centerline latch mechanisms and payload bay doors. The problem of misalignment due to thermal distortion was also considered. The tool had to close the doors having 5.05 cm (1.99 inches) misalignment in the y-axis and 10.97 cm (4.32 inches) misalignment in the z-axis. Misalignment in the x-axis was considered negligible because the four passive shear fittings align the doors in the x-direction. The tool provides a load path for y and z forces on the payload bay doors to maintain the Orbiter's structural integrity during reentry.

The centerline latch tool's controls, handgrips, operating forces, and procedures had to be within the capabilities of a partially restrained, EVA crewmember in a zero-gravity environment. These design requirements are set by the Shuttle EVA Description and Design Criteria Document (JSC-10615). Another requirement is that the tool be provided a safety tether attach point since it will be transported or handled during EVA. The tool also had to retain itself in position while being used by the crewmember.

The centerline latch tool (Fig. 4) consists of a frame, a screw/nut drive assembly turned by a ratchet that pivots in the frame, and the latch. The ratchet handle folds down into a stowed position to conserve space. The release button, which is used to deploy the tool latch, can be depressed from either side of the tool frame. It has a safety catch, also on both sides, such that it cannot be inadvertently depressed. The installation sequence is shown on Fig. 5.

INSTALLATION

The tool is installed by first inserting it on the failed centerline hook latch. Then the tool is rotated to brace it in place (Fig. 6). The safety catch is removed on the release button to be depressed. When the release button is depressed, the tool latch is deployed. The tool latch bypasses the existing hook latch regardless of the position of the centerline hook latch. The ratchet-handle is now unfolded. In this configuration, the crewmember holds the tool and extends the screw by ratcheting until a force is applied on the centerline latch passive roller, closing and securing the door. The sleeve on the ratchet handle is raised and the handle folded to the stowed position.

One tool is installed on each centerline latch in the disabled gang in the same sequence as normal door closure. After installing the last tool, the crewmember is ready to reenter to the crew module.

TESTING

The centerline latch tool has undergone development and evaluation by crewmembers and NASA personnel. Extensive testing and training have also been done using the full-scale mockup of the Orbiter in the Weightless Environment Training Facility (WETF) at the Johnson Space Center. This testing determined that the centerline latch tool was within extravehicular capabilities and workload limits.

A qualification test fixture was also built to simulate the loading on the latches. The centerline latch tool was installed on the test fixture latches. Then, using a hydraulic cylinder, the tool reacted the loads that it would see during reentry.

CONCLUDING REMARKS

The flight tools are stored onboard the Cargo Bay Stowage Assembly, a stowage container located in the payload bay, during the Shuttle flights. The centerline latch system is a reliable mechanical system; however, like any mechanical system, it is possible that a malfunction could occur that could cause an unsafe reentry of the Orbiter. This backup tool will be available as a safety device for the Orbiter.

REFERENCES

1. McAnally, Bill M.: Space Shuttle Orbiter Payload Bay Door Mechanisms. Paper presented at the 13th Aerospace Mechanisms Symposium (Johnson Space Center, Texas), April 26-27, 1979.

2. Acres, William R.: Orbiter Door Closure Tools. Paper presented at the 14th Aerospace Mechanisms Symposium (NASA Langley Research Center, Hampton, Virginia), May 1-2, 1980.

TABLE 1.- DOOR CLOSURE FAILURES

TYPE OF FAILURE	CAUSE	ACTION
One or both doors will not close	Door drive system failure	Attach the winch hook to the affected door and manually close the door. Actuate the bulkhead latch system.
	Door drive system failure and jam	Cut the six drive tubes on the affected door with the tubing cutter and manually close the door using the winch. Actuate the bulkhead latch system.
Bulkhead latch system fails with the latch hook greater than 37° from the closed position	Latch actuator fails or jams	Install the three-point latch tool on the end of the affected door starting with the number 1 latch. Proceed in order to the number 4 latch, closing the door at each position before proceeding to the next latch.
Bulkhead latch system fails with the latch hook less than 37° from the closed position	Latch actuator fails or jams	Remove the connector bolt from the actuator linkage with the bolt extractor. Manually backdrive the latch hooks until the three-point latch tool can be installed on the number 1 latch; proceed in order to the number 4 latch, closing the door at each position before proceeding to the next latch.
Centerline latch system fails with the hook latch in any position	Latch actuator fails or jams	Install the centerline latch tool on the affected centerline latch. Proceed in order to the next centerline latch.

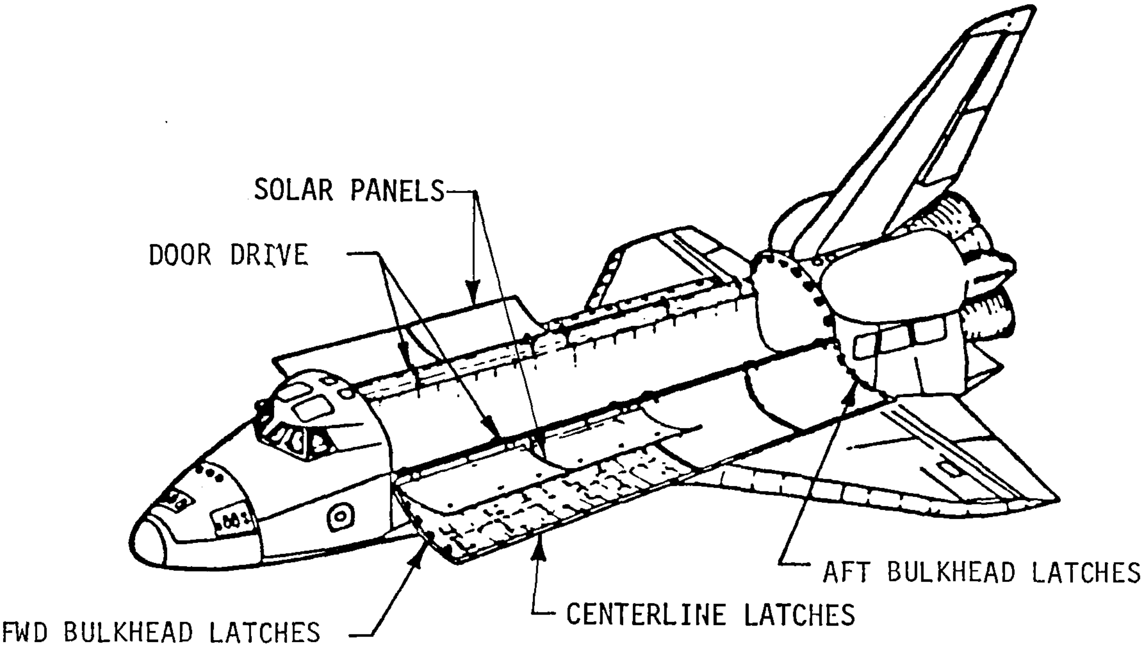


FIGURE 1. - PAYLOAD BAY DOOR SYSTEM

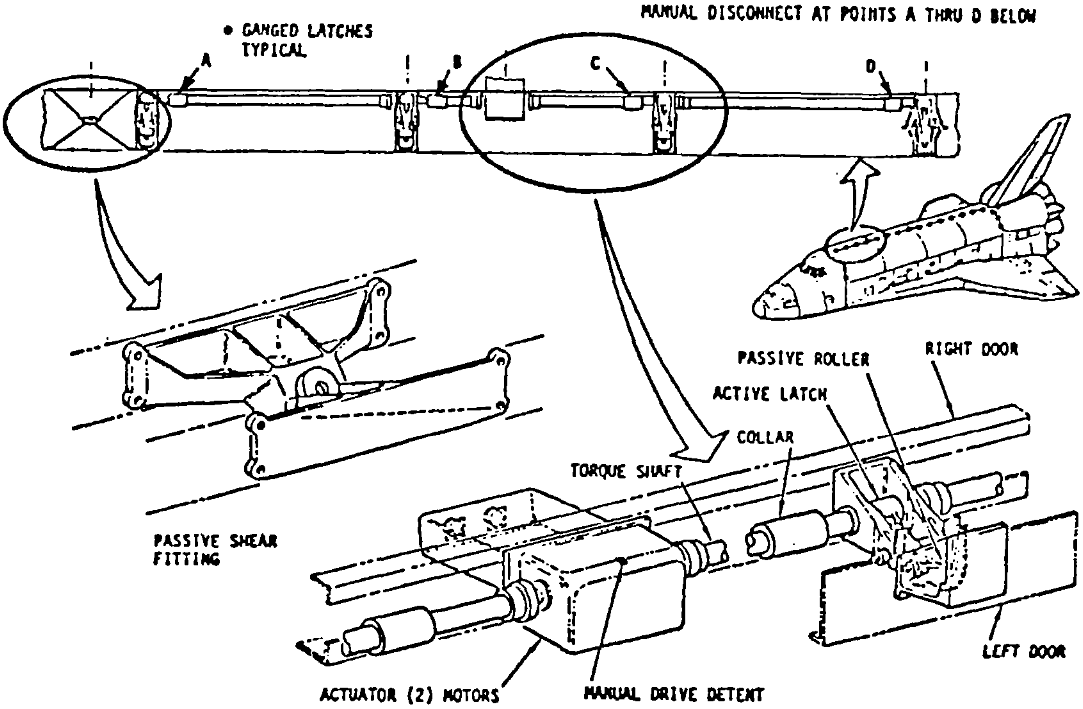


FIGURE 2. - PAYLOAD BAY DOOR CENTERLINE
LATCH SYSTEM

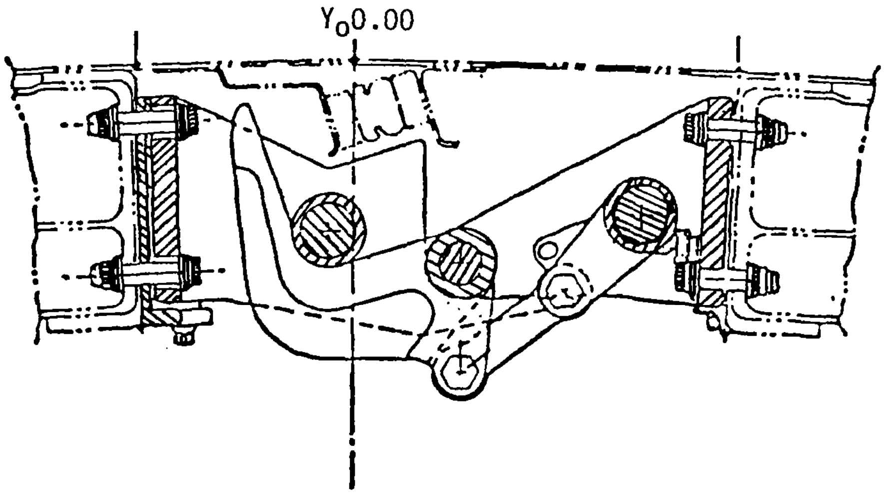


FIGURE 3. - CENTERLINE LATCH ASSEMBLY,
TYPICAL (16 LOCATIONS),
VIEW LOOKING FWD

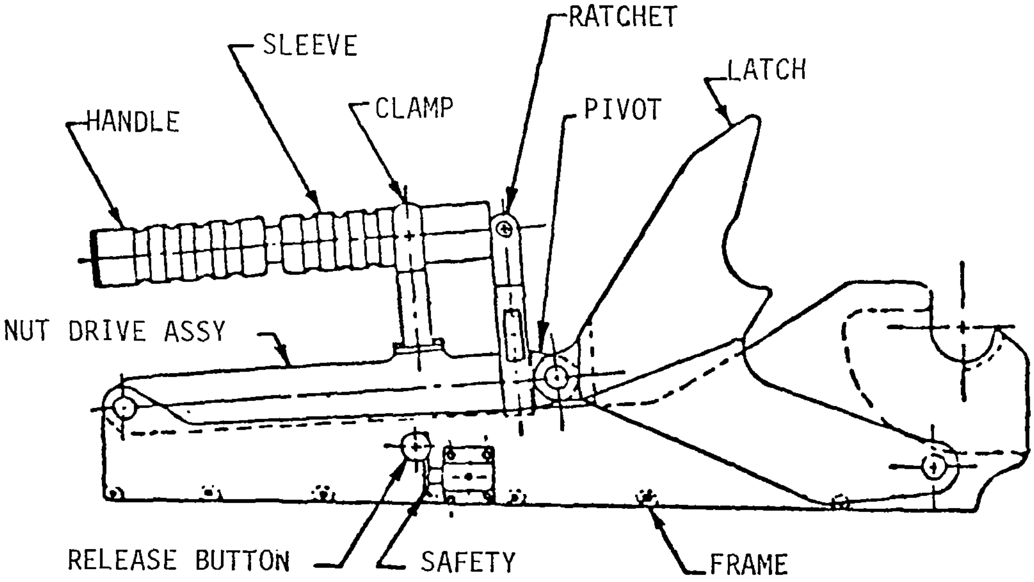
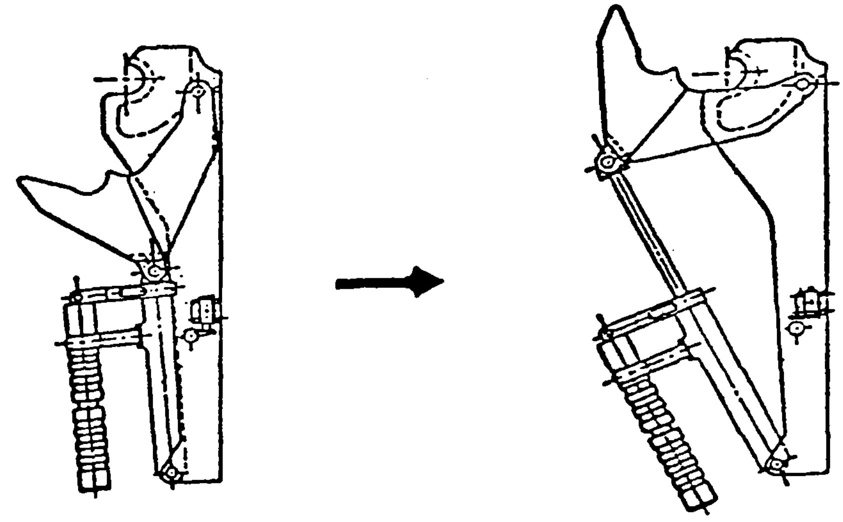
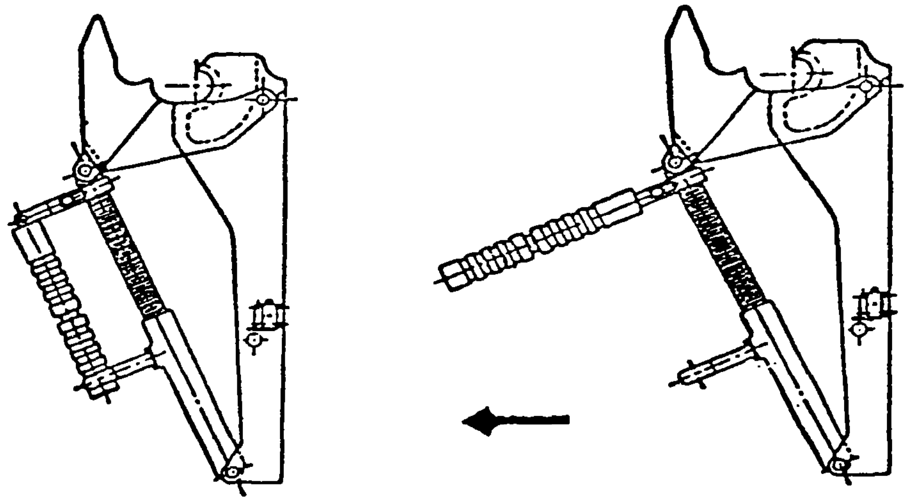


FIGURE 4. - CENTERLINE LATCH TOOL



STEP 1
INSTALL ON DISABLED LATCH

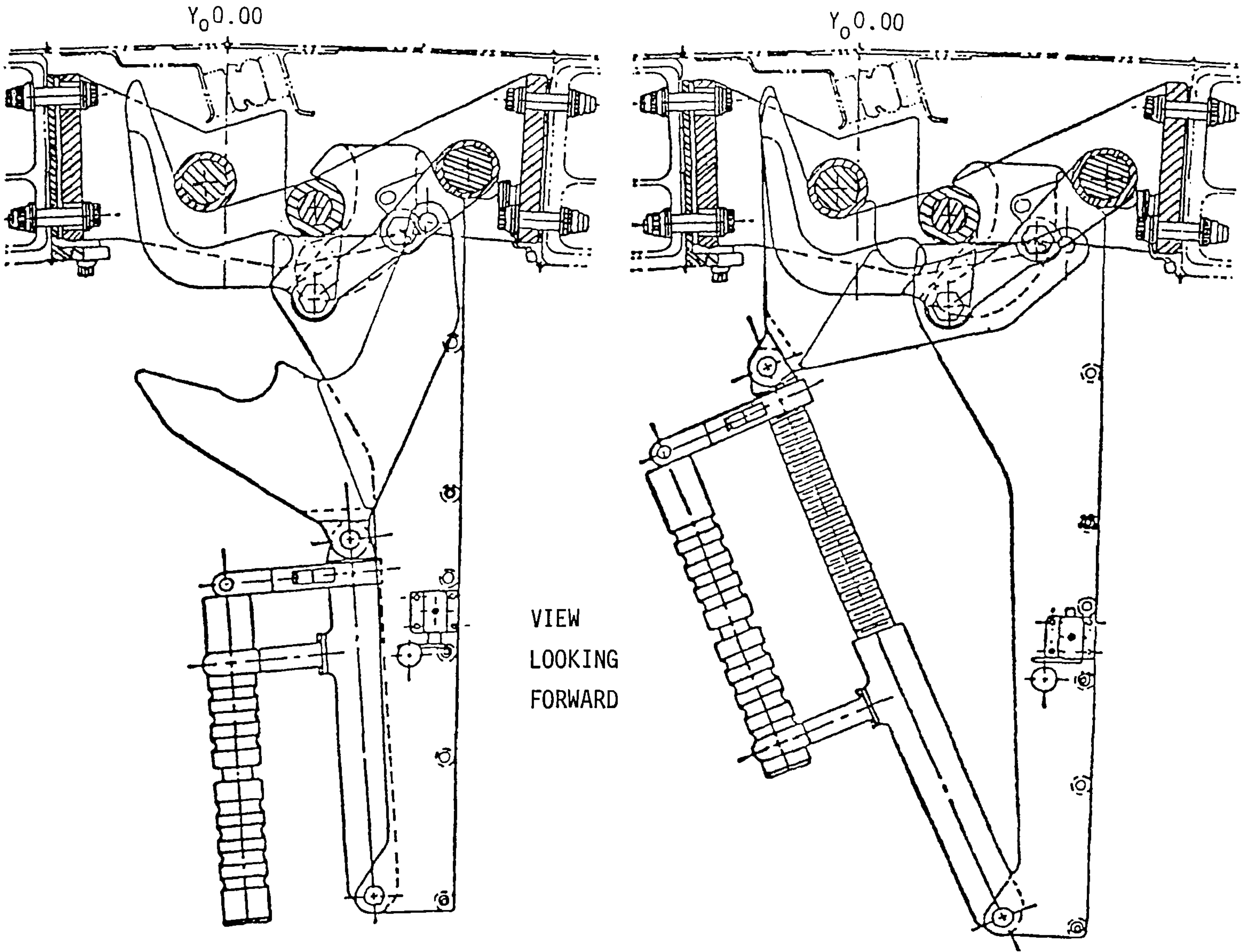
STEP 2
RELEASE HOOK



STEP 4
STOW HANDLE

STEP 3
EXTEND DRIVE SCREW

FIGURE 5. - CENTERLINE LATCH TOOL
INSTALLATION SEQUENCE



(1) TOOL IS INSERTED ON THE HOOK PIVOT SHAFT AND BRACED AGAINST THE BELLCRANK.

(2) TOOL LATCH IS RELEASED AND LOCKED IN PLACE.

FIGURE 6. - CENTERLINE LATCH TOOL INSTALLATION

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SPACECRAFT LAUNCH VEHICLE
EVENT SEQUENCING SYSTEM

By

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ABSTRACT

This paper describes the design and operation of a combination of explosive devices and mechanisms that are used to provide sequencing signals and events for the upper stages of a multistage launch vehicle. The launch vehicle is a three-stage vehicle with the Atlas booster as the first stage and Thiokol Star 48 solid motors providing propulsion for the 2nd and 3rd stages. The 1st/2nd stage separation is initiated by redundant discrete electrical signals that originate in the Atlas booster. All subsequent events are controlled by explosive/mechanical components assembled and installed in a subsystem called the Event Sequencing System. No electrical power or signal is required for subsequent events.

The upper stages are designated the SGS-II Stage Vehicle System.

INTRODUCTION

The Event Sequencing System evolved from a requirement commencing with separation from an Atlas E/F booster to perform all functions necessary to place a NAVSTAR Global Positioning satellite into a transfer orbit. Two tandem Star 48 solid-propellant motors provided sufficient total impulse to achieve the necessary apogee velocity. A method of providing the following functions in a sequential manner was required:

1. 1st/2nd Stage Separation
2. Simultaneous Ignition of 8 Spin Gas Generators
3. 2nd Stage Solid Motor Ignition
4. 2nd/3rd Stage Separation
5. 3rd Stage Solid Motor Ignition
6. 3rd Stage/Spacecraft Stage Separation
7. Release of Tumble Weights

The Event Sequencing System is an integrated system which performs items 2 through 7.

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TRADE STUDIES AND RISK ASSESSMENT

Three major types of systems were studied for Event Sequencing: Electromechanical, Electronic and Explosive. Safety, reliability, simplicity of design (including telemetry interfaces), cost, weight, flight environment, implementation schedule, field station operations and procedures, amount of ground support equipment required, and extent of company experience with each system were considered. Cost and schedule were of paramount importance. The system had to be designed, developed and qualified for flight within one year.

The major alternative to the explosive/mechanism system was the use of electromechanical timers. The complexity of electrical system design and checkout, the historical problems associated with electromechanical timers, the additional amount of telemetry required, and the severe schedule problems involved with electromechanical timers led to selection of the explosive/mechanism system.

The explosive/mechanism system was selected because it was safe, simple, highly reliable, weighed less than competing systems, and could be designed, developed and tested within the allotted schedule. The selected system used less electrical power, required no telemetry, and eliminated the need for field checkout and ground support equipment.

SYSTEM DESCRIPTION

The system consists of components listed below, together with Explosive Transfer Assemblies (ETA), and inert parts necessary to connect the components together.

QUANTITY	NOMENCLATURE
2	1-second delay
2	2.1-second delay
2	10.2-second delay
2	128.4-second delay
2	141.7-second delay
2	203.6-second delay
20	Through-Bulkhead-Initiator (TBI)
4	TBI Operated Bolt Cutters
2	TBI Operated Cable Cutters
4	Separation Plane Initiators (SPI)

A functional schematic showing the organization of the components into the system is shown in Figure 1 and 1A. An exploded view of the SGS-II Stage Vehicle System is shown in Figure 2. Figure 3 is a photograph of the SGS-II taken during development testing.

SYSTEM OPERATION

The system sequencing is initiated by the separation of the 1st/2nd stages which pulls an activating rod from each of two Separation Plane Initiator Mechanisms (SPIM). The SPIM output initiates the following sequence of events:

Sequence 1

Initiates redundant one-second pyrotechnic time delays whose output is used to:

A. Ignite 8 gas generators that are used to spin the 2nd and 3rd stages and the spacecraft to 75 RPM.

B. Initiate redundant 141.7-second pyrotechnic delays.

Sequence 2

Output from the 141.7-second delays initiate:

A. The second stage Star 48 motor.

B. Redundant 128.4-second time delays.

Sequence 3

Output from the 128.4-second delays initiates redundant bolt cutter mechanisms which sever the bolts on a V-band clamp assembly, thus releasing the structural attachment between the 2nd/3rd stages. Coiled helical compression spring actuators provide the separation force.

Sequence 4

The third stage segment of the system is initiated by the separation motion which activates two SPIM.

Sequence 5

Output of the two SPIM initiate redundant 10.2-second pyrotechnic time delays. Output of each time delay is manifolded to accomplish the following:

A. Initiate the 3rd stage Star 48 motor.

B. Initiate redundant 203.6-second time delays.

Sequence 6

Output from each 203.6-second delay initiates:

A. Redundant bolt cutter mechanisms which sever the bolts on a V-band clamp assembly, thus releasing the structural attachment between the 3rd stage and spacecraft. Coiled helical compression springs provide the separating force.

B. Redundant 2.1-second time delays.

Sequence 7

Output from each 2.1-second delay initiates redundant cable cutters which release a tumble weight that prevents the expended third stage from recontacting the spacecraft.

COMPONENT DESCRIPTION

Explosive Transfer Assemblies (ETA)

The ETA consists of a metal-clad explosive core (mild detonating cord) assembled into a stainless steel tube which contains all the products of detonation. This material is fabricated into ETA lines of the required length by adding identical end tips and the appropriate size threaded fitting at each end (Figure 4). All explosive material is hexanitrostilbene, especially developed for high-temperature applications. The ETA transfers the sequencing signal from component to component with a detonation velocity of approximately 6000 meters/sec (20,000 ft/sec). The ETA can be formed into any shape in which a similar piece of stainless steel tubing could be formed using a one inch minimum bend radius. Approximately three-quarter million ETA lines have been manufactured to date.

Through-Bulkhead-Initiator (TBI)

A TBI is a bar of steel with non-connecting holes bored on its centerline from each end. Figure 5 shows a cross-sectional view of a TBI configured for an ETA tip input. A high-explosive donor charge is press loaded into the cavity against the bulkhead on the input side, and a receptor charge is loaded against the bulkhead on the output side. The donor charge is initiated by the ETA tip, and resulting shockwaves are transmitted through the bulkhead to initiate the receptor charge, which then ignites the TBI output charge. The output charge is tailored and sized to a specific objective. The bulkhead remains intact and is designed to retain a pressure of 5516 $\frac{N}{CM^2}$ (8000 PSI) at a temperature of 149°C (300°F).

Bolt and Cable Cutters

The bolt cutter (Figure 5) is a self-contained device consisting of an explosive cartridge (TBI), a bolt cutter body, a guillotine piston/knife blade held and positioned in the body by a shear pin, and an anvil. In operation, the pressure resulting from the output of the explosive charge builds up behind the piston/knife blade, causing it to shear the shear pin and impact against the anvil. The bolt cutter is used to cut a 0.792 CM (.312 IN) diameter A-286 stainless steel stud heat treated to 117 K $\frac{N}{CM^2}$ - 138K $\frac{N}{CM^2}$ (170-200 KSI). The cable cutter is similar in operation to the bolt cutter except that it has a removeable anvil, which allows the cutter to be installed on a cable with fixed ends.

Pyrotechnic Time Delays

Figure 6 shows the incorporation of Small Column Insulated Delay (SCID) fuse into a delay module designed for ETA end-tip initiation. Shock/pressure from an ETA end tip drives a firing pin into a percussion primer, and hot gases from the primer ignite a pickup charge on the end of the SCID. Burning rate and length of SCID control the length of time delay. The other end of the SCID is fitted with a booster charge that produces a high-order detonation output to initiate the interconnecting ETA lines and the other time delay in the module. SCID fuse is a deflagrating pyrotechnic (32.8 grains/meter [10 grains/ft]) encased in a continuous lead sheath. It is similar in appearance to lead solder. Burning rates of SCID in this application vary from .20 $\frac{SEC}{CM}$ (.5 $\frac{SEC}{IN}$) to 1.38 $\frac{SEC}{CM}$ (3.5 SEC/IN).

TIME DELAY REQUIREMENTS/RESULTS

The delay limits imposed were a 3 sigma value of ± 10% from the nominal over a temperature range of 10°C to 26.7°C (50°F to 80°F).

Representative actual time delay periods from production delays are shown in Table 1. Pyrotechnic delays are temperature sensitive and tend to time out faster at high temperature and slower at low temperatures. Nominal times also tend to increase at the rate of 1% to 2% a year as a result of aging.

TABLE 1. TIME DELAY TEST RESULTS

TEMP	DELAY TIME (SEC)					
	1.0	141.7	128.4	10.2	203.6	2.1
10°C(50°F)	1.01	146.90	127.15	10.95	209.10	2.05
18.3°C(65°F)	1.00	135.60	125.68	10.98	209.45	2.09
	1.00	136.75	123.73	10.69	202.55	2.12
	1.01	139.15	124.35	10.65	199.50	2.11
	1.00	138.76	122.53	10.84	193.05	2.06
	.99	132.56	129.35	10.61	209.65	2.10
	.99	138.64	129.40	10.68	203.45	2.13
26.7°C(80°F)	1.05	134.45	125.45	10.21	196.50	2.03

SEPARATION PLANE INITIATOR MECHANISM (SPIM)

The SPIM is a simple mechanism which performs a very important function. The explosive components installed on the second and third stages are initiated by redundant SPIM mounted at the separation planes. The SPIM is fired by a standard firing pin and percussion primer arrrangement. The separation motion between stages cocks the spring-driven firing pin and in the same movement releases the sear and allows the pin to drive into the percussion primer (Figure 7). The percussion primer initiates a pickup charge which initiates a standard ETA end tip.

A similar design is commonly used on military aircraft escape systems for initiation of the escape system and for parachute reefing line cutters. The Apollo space vehicle used such devices in its parachute recovery system.

SAFETY ASPECTS

The system met all the range safety requirements of SAMTEC 127-1, CHANGE 3, with the exception of Para. 3.4.6.4, Volume I, which required the use of a remotely controlled safe and arm (S&A) device in the solid motor ignition system. The need for an S&A device was obviated by the use of the non-electric SPIM which initiates the motor-ignition explosive trains only upon stage separation.

Inadvertent motor ignition is prevented by the following: installation of the output ETA line to the SPIM late in the launch preparation cycle; use of a flagged removeable safety pin and safety plug for the output port; placement of a shoulder on the firing pin to prevent the pin from being pushed in; and installation of integral mounting bracketry on the aft stage to prevent the pin from being pulled out except by stage separation. The weight of one motor and the space vehicle is greater than the force the separation springs provide; therefore, no separation would occur at either first/second or second/third separation planes if a clamp band assembly inadvertently separated while on the launch pad.

The use of the SPIM concept was approved by Range Safety and the upper stages designated the SGS-II Stage Vehicle System are scheduled to be launched from Vandenberg Air Force Base in 1982.

CONCLUSION

The Event Sequencing System represents a unique application of explosives and mechanisms to accomplish operations formerly performed by electromechanical and electronic systems. Application of such a system is recommended for sequencing events where the timing variations inherent in the system are acceptable; and high reliability, safety, relatively low cost and weight, and absence of field station checkout and equipment are desired.

ACKNOWLEDGMENTS

The system was designed for the Space Division of the Air Force Systems Command. All component parts were designed and built by Teledyne McCormick Selph, Hollister, California, to a system specification provided by McDonnell Douglas Astronautics Company, Huntington Beach, California.

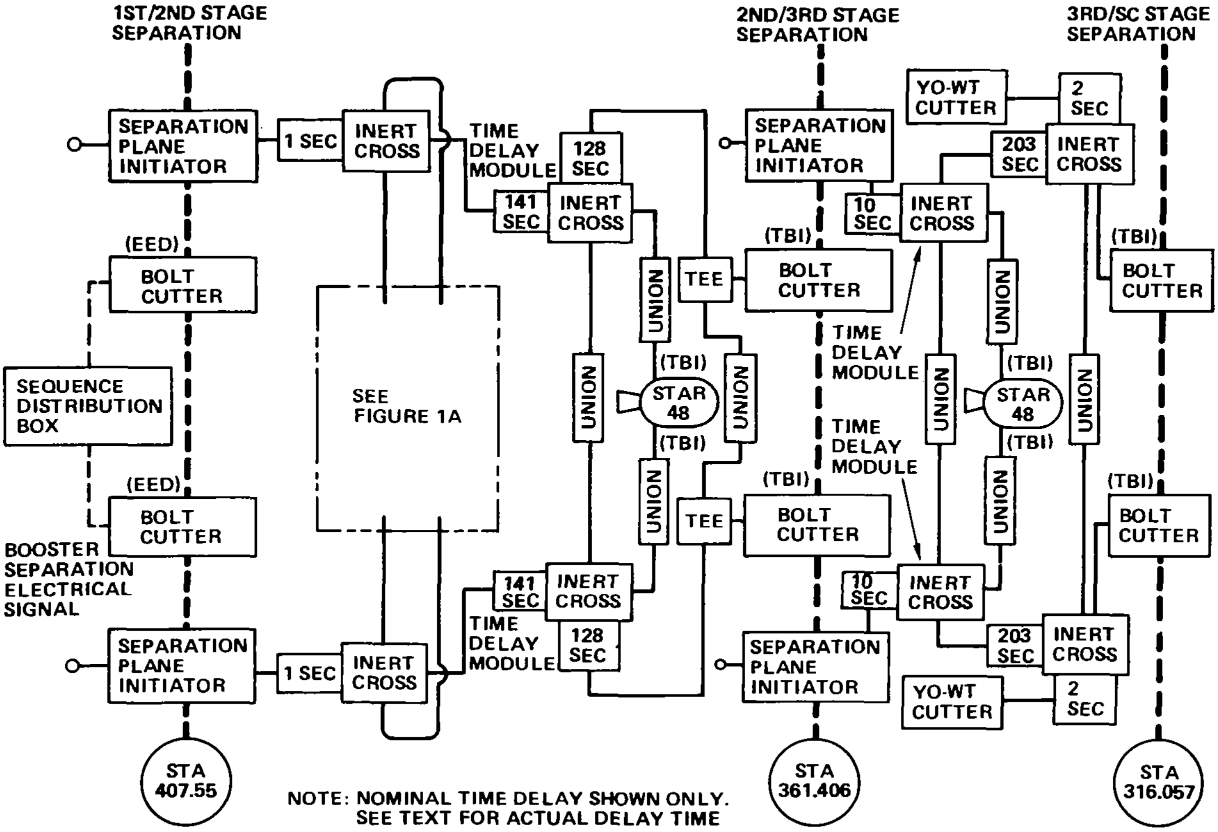

Figure 1. Event Sequencing System Schematic

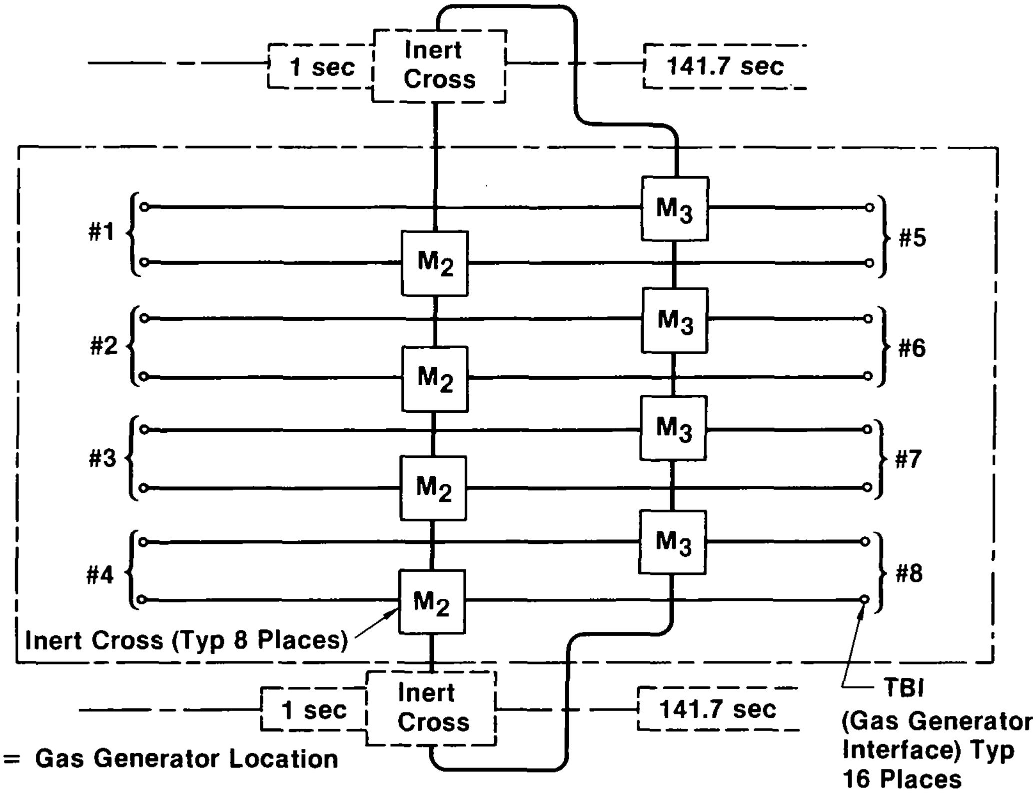

Figure 1a. Gas Generator Manifolding

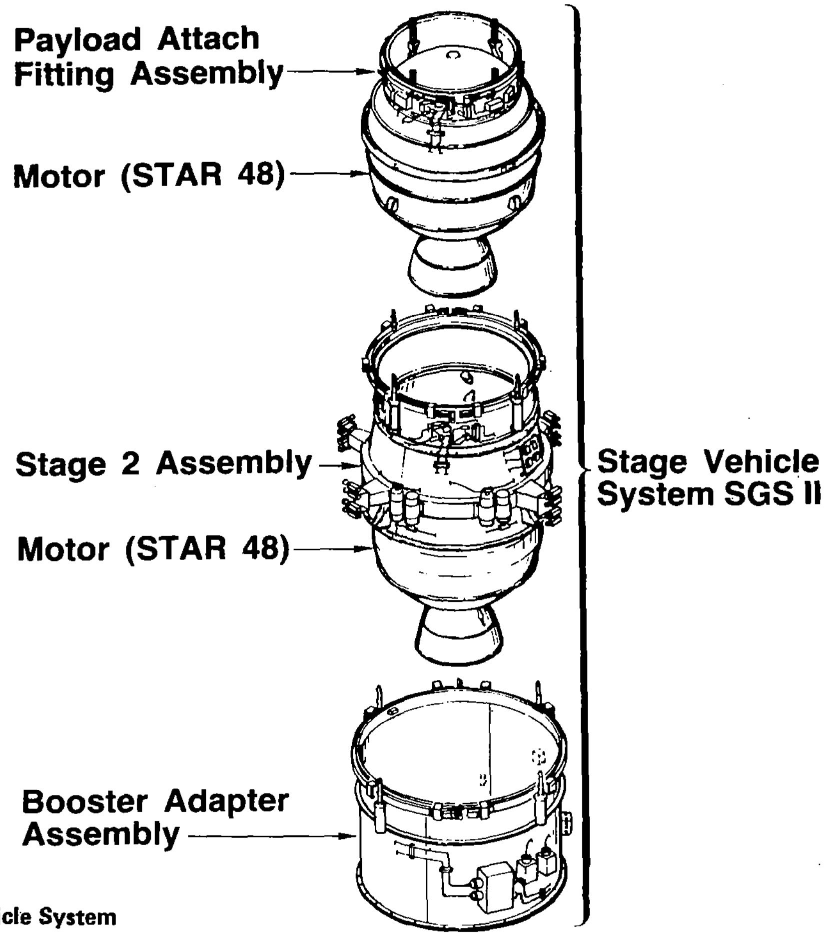

Figure 2. Stage Vehicle System

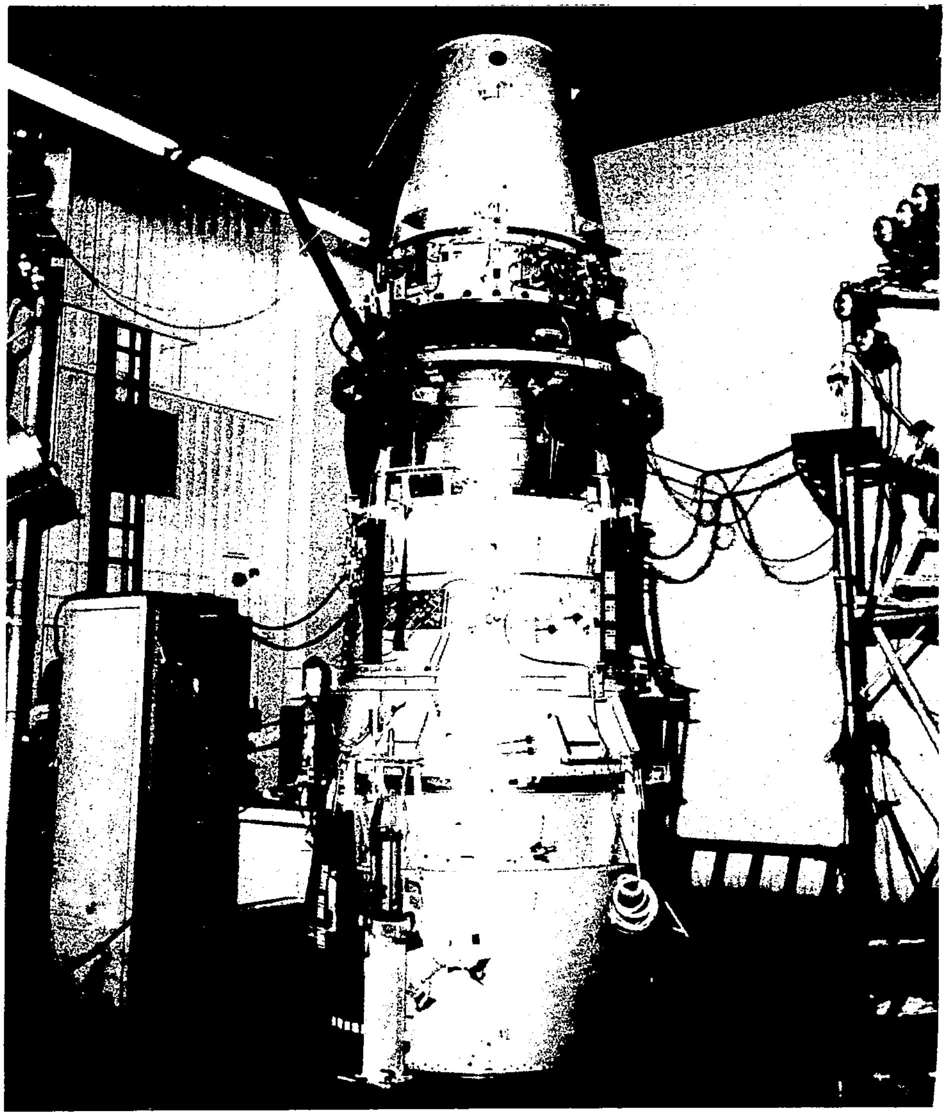

Figure 3. Stage Vehicle Systen

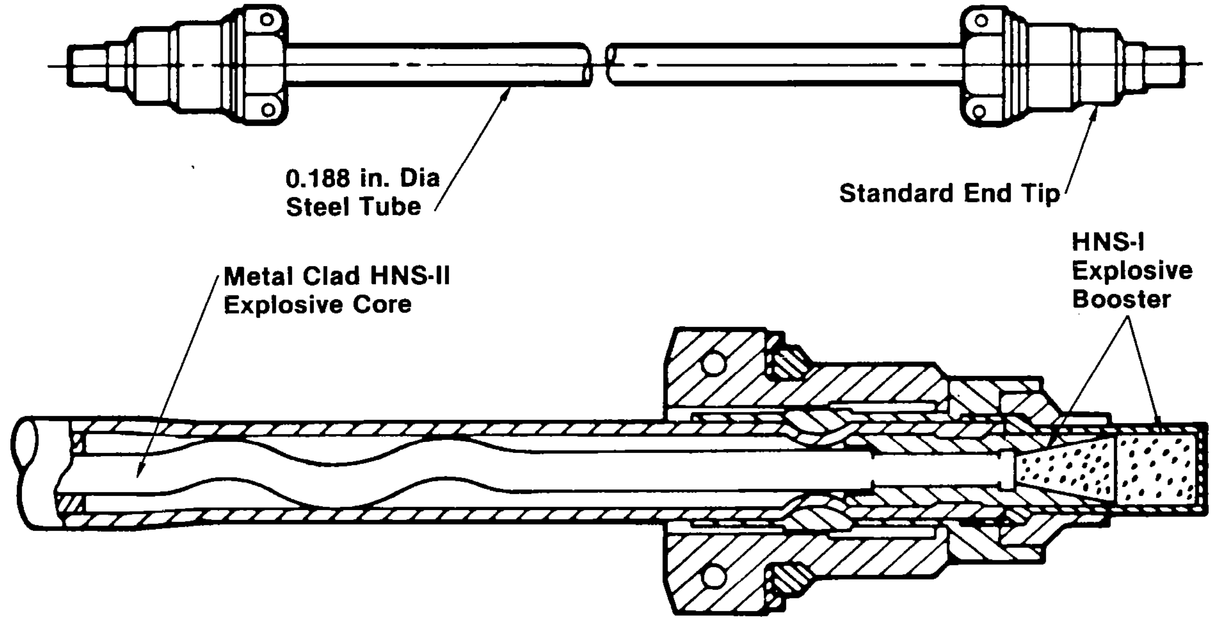

Figure 4. Explosive Transfer Assembly (ETA) Line

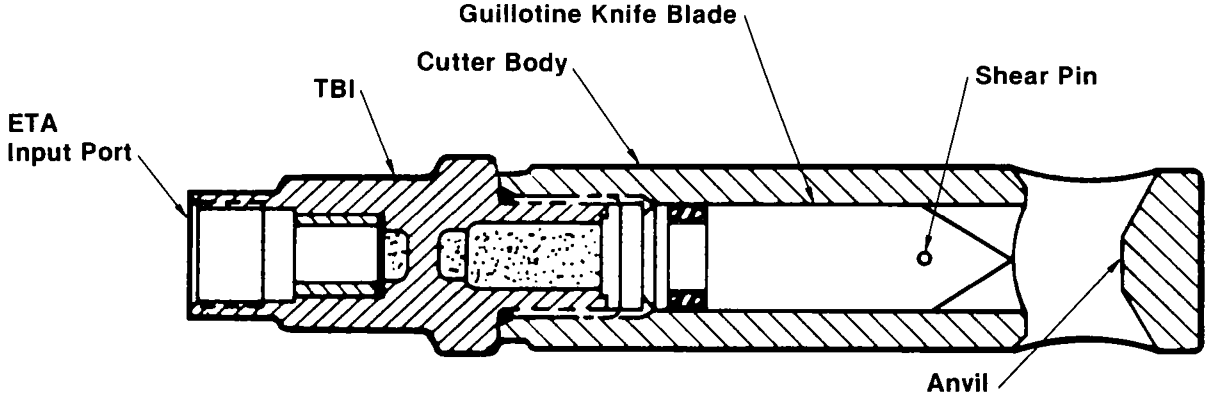

Figure 5. Through Bulkhead Initiator (TBI)/Bolt Cutter Cross Section

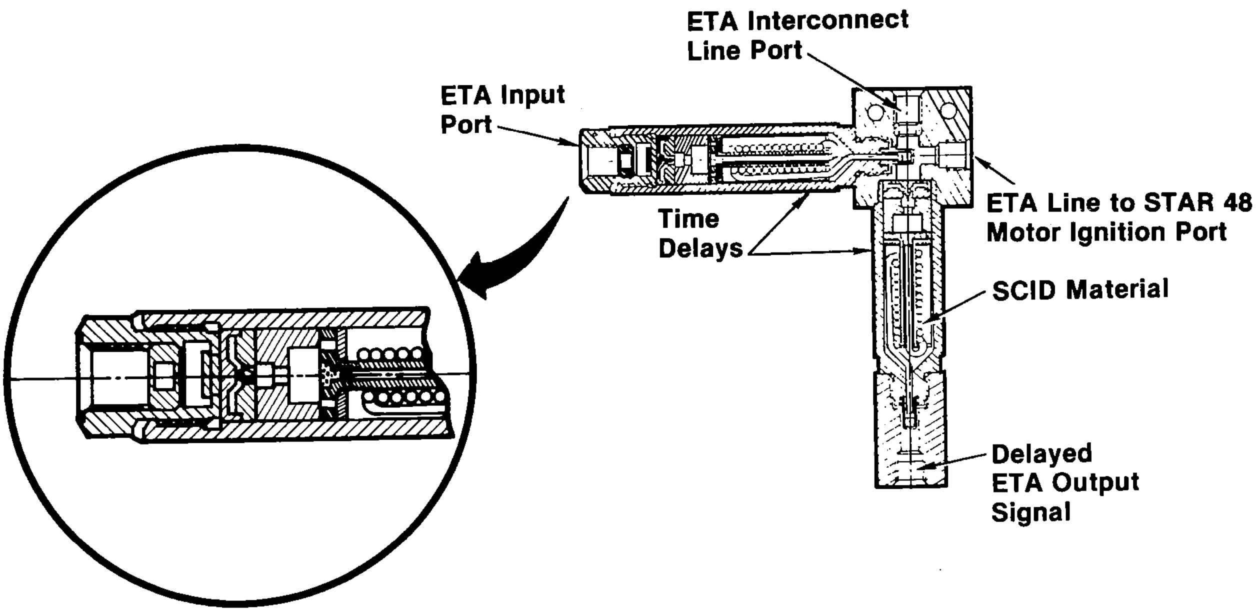

Figure 6. Pyrotechnic Time Delay Modules

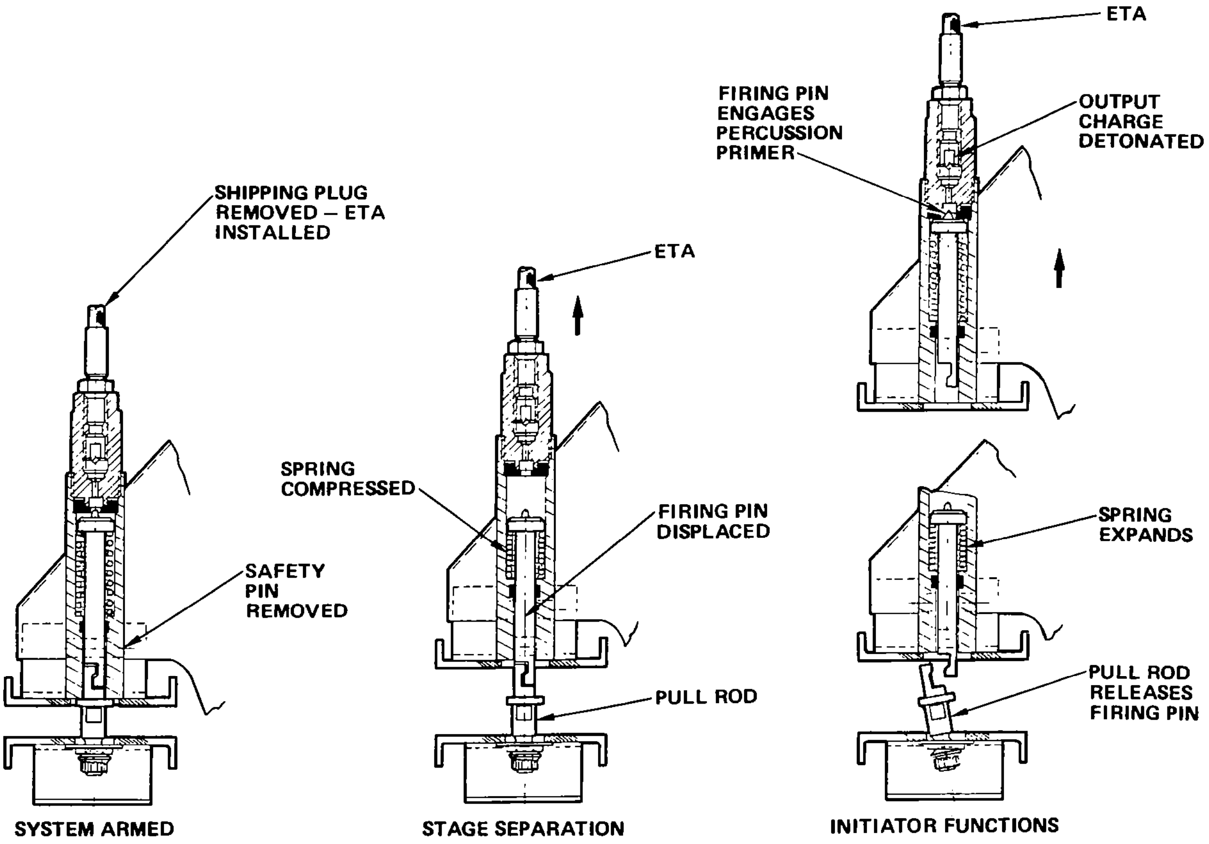

Figure 7. SPIM Separation Sequence

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Mr. Noel is currently a senior engineer/scientist with McDonnell Douglas Astronautics Company. His experience includes that of being mechanical group engineer on the SGS-II program and principal designer of the event sequencing system. He has previously been the principal designer for the Delta launch vehicle 8-foot fairing separation system and the explosive system used to ignite and separate the Delta solid boosters. He participated in the design and testing of explosively actuated mechanisms and systems on several programs including the Gemini, Manned Orbiting Laboratory, and Spartan missile. Mr. Noel received his B.S. degree in Aeronautical Engineering from Northrup Institute of Technology in 1960 and has pursued additional studies at the University of California-Los Angeles.