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Rendezvous Launch Operations Planning

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This paper deals with the inception and evolution of the simultaneous launch countdown technique. Furthermore, it explains the implementation of the countdown and recycle plans and how the Martin Company's testing and scheduling of the Gemini Launch Vehicle (GLV) is affected by a rendezvous mission.

Program Objective

Perhaps the most important objective of the Gemini program is to prove and perfect the rendezvous technique. Since this technique is the foundation upon which the moon-bound Apollo program is based, its perfection is required in order to proceed with the overall manned space program.

In addition, space rendezvous opens up a myriad of possibilities such as:

1. Rescue of crew members stranded in orbit;
2. Propellant transfer from an orbiting tanker to an empty stage and spacecraft;
3. Crew transfer from a ferrying vehicle to a fully-fueled orbiting booster;
4. Maintenance stations in permanent orbit capable of repair and launch of outbound vehicles;
5. Assembly of a manned spacecraft and fueled propulsion stage;
6. Crew and supply transfer to and from a manned orbiting laboratory.

Gemini Rendezvous

The Atlas D launch vehicle is used to place an Agena D Target Vehicle (ATV) in space at near-orbital velocity. Since the Atlas does not provide sufficient power to insert the ATV into earth orbit, the Agena engine is started and propels the ATV into orbit. The Agena propulsion system is then shut down and preserved for further use, either for orbit corrections or maneuvers while docked with the Gemini spacecraft.

Ground tracking stations accurately verify the ATV orbit and velocity and feed this information to computers at Houston and Goddard. One of the computer outputs gives the best time period for liftoff of the Gemini Launch Vehicle. This time period is referred to as the launch "pane" and is a relatively short time (approximately twenty minutes). However, by using the ATV engine and changing orbit to conform more closely to that of the Gemini spacecraft, the launch pane can be extended into a "window" of about 2½ hours. This correction would be made after the Gemini launch.

If the Gemini cannot be launched within the window for any given day, the launch must be delayed at least until the following day. Since the ATV has an on-orbit lifetime of only five days, the mission would fail if Gemini does not attain orbit within this timespan.

Same Day Launch

The original concept of the Gemini rendezvous called for launch of the ATV on a particular day, followed approximately twenty-four hours later by the Gemini launch. Early in the program, however, it became obvious that since the Agena had only a five-day lifetime, scheduling the launch of the Gemini on the same day would provide the advantage of an extra day in which to rendezvous, thereby enhancing the probability of success proportionally.

An additional advantage to a same-day launch lies in the proven fact that the closer a launch system gets to T-zero, the greater the probability of meeting the given launch time; e. g., the highest probability of launch occurs the instant before lift-off. By not committing the Atlas-Agena until the Gemini is late in its countdown, the odds of an on-time Gemini launch are considerably increased.

Another factor considered was the fact that the longer the ATV remained in orbit, the greater the probability of its failure.

When all these factors were combined, the need for launching the Gemini immediately following the Agena became obvious. Naturally, the Gemini would not be launched until after good data had been received on the Agena orbit. This occurs over Australia. Once a good ATV orbit is confirmed, the Gemini is committed for a launch approximately one revolution after Agena liftoff.

Simultaneous Countdown

This then meant that the two systems, Atlas-Agena and Gemini-Titan, must be counted down simultaneously with the Agena launch occurring in the Gemini countdown.

In the time period between the Agena launch and the anticipated Gemini liftoff, certain factors could contribute to a scrub and consequent mission failure unless prior planning makes their possibility remote.

The most important factor to be avoided is an Agena launch while an unresolved or latent problem exists somewhere in the Gemini launch system. The Gemini launch vehicle, spacecraft, Eastern Test Range, and worldwide tracking and telemetry networks must be in a 100% "GO" condition when the Agena is launched. Also, prior planning must consider possible malfunctions or anomalies occurring within a system during the ninety-five minutes prior to the Gemini launch and make provisions for their expeditious rectification.

Recycle

Should the Gemini fail to be launched within the allocated time (launch window) on the same day as the Agena, there are still four days remaining in which to launch. Upon scrub, all Gemini systems immediately begin preparations for another attempt. Naturally, the earlier the scrub occurs, the more time there is available in which to recycle the systems.

The capability of being able to launch during the launch window on any one of five successive days requires a precise scheduling of the many operations to prepare the vehicle and spacecraft.

The activities in the timespan from the end of the launch window on one day until the beginning of the launch window on the next day is defined as "recycle." This time is approximately nineteen hours.

A basic assumption necessary to accomplish recycle is that whatever restrained launch initially would not continue to do so on consecutive days. This assumption was based on several considerations:

1. Weather was virtually eliminated as a factor on the first day, since the Agena would not be launched if weather for Gemini was forecast to be marginal;

2. The systems design and checkout was such that maximum reliability and minimum failure rate just prior to launch would be attained;[1]

3. The countdown was written such that all major testing took place before the Agena launch. Most tests subsequent to that time are repetitive or confidence type checks.

The nineteen hour turnaround of launch systems for Gemini is no simple task and requires a great deal of pre-planning. Studies indicated that all tasks could be accomplished within the allotted time provided several design and operational changes were made.

Propellant Temperature Problem

The Gemini launch vehicle uses hypergolic propellants - the fuel, 50% hydrazine combined with 50% unsymmetrical-dimethyl hydrazine; and oxidizer, nitrogen tetroxide.

In order to increase the mass flow rate, specific impulse, and consequently the payload capability, the propellants are "conditioned" or cooled prior to loading. The desired temperature at liftoff in each airborne tank is precalculated in an elaborate computer run which considers many variable factors, such as:

1. Initial loading temperatures of the propellant;
2. Meteorological conditions, especially wind speed, temperature, and dew point during the time the propellants are loaded aboard the vehicle;
3. Position of the vehicle erector and the erector curtains which surround the vehicle.

The time required to recondition propellants after a scrub and during the recycle period in preparation for a launch the next day is a function of the temperature of the propellants at the time unloading is completed, and the temperature required when reloading begins. Since these temperatures are a function of the time the propellants are in the vehicle, it can be said that, normally, the time required to recondition propellants is directly proportional to the time the propellants are aboard the launch vehicle.

The period available for reconditioning propellants after allowing time for unloading and reloading was beyond the capability of the heat exchangers. After the cost and feasibility of many improvements were considered, it was decided to install a completely redundant conditioner and ready storage vessel (RSV) for each propellant.

This virtually eliminated the need for propellant conditioning during the recycle period, since the use of dual storage vessels allowed one load of propellant to be conditioned and ready. This cold propellant could then be loaded into the launch vehicle as soon as the warm propellants from the previous launch attempt were detanked.

The addition of redundant conditioners also allowed the cooling rate to be substantially increased by "double passing" the propellants through both heat exchangers. Also, the secondary conditioner could be used in the event of a primary system failure.

Prevalve Opening Time

The engines of the Gemini launch vehicle are isolated from the tanks by the use of zero-leak prevalves located at the interface between the engine and the propellant feed system. These valves are operated to the open position by pressure cartridges (squibs) as late in the countdown as possible. Their opening allows propellant to enter the engine and associated plumbing.

Some of the plumbing in the Stage I oxidizer system involves a standpipe which was developed to damp out regenerative oscillations (pogo). This surge chamber required a manual charging operation which set the bubble size in the standpipe. Because of safety considerations, this occurred at approximately T-140 minutes.

This early prevalve opening was unacceptable for a rendezvous mission for two reasons:

1. It committed the Gemini launch vehicle to flight before the Agena was launched;
2. It increased the time, hence the probabilities of a scrub after prevalve opening.

A scrub after prevalve opening greatly complicates recycle because (1) the lifetime of some engine seals is limited after being exposed to liquid propellants and (2) the reloading of propellants must be done with loading dynamics directly applied to the engine.

Therefore, the Martin Company under direction of the Space Systems Division of the Air Force developed an automatic pogo standpipe charging system which allowed the oxidizer prevalves to be opened remotely from the blockhouse late in the countdown.

Simultaneous Operations

Propellants. Since the propellants utilized in the launch vehicle react upon contact with each other, it is general practice to schedule fuel and oxidizer operations separately.

Normally, a detanking operation involving separate unloading of fuel and oxidizer takes approximately four hours. A waiver was requested of the Missile Handling Branch, Air Force Eastern Test Range, to allow simultaneous unloading of the two propellants. This waiver was granted provided certain precautionary and inspection procedures were followed.

1. Oxidizer was started out of the vehicle and after several minutes the unloading was stopped and an inspection made for leaks;

2. If no oxidizer leaks were apparent, the same procedure was accomplished for fuel;

3. If no fuel leaks were found, simultaneous unloading commenced.

This resulted in a net saving of 1½ hours during a recycle operation.

Ordnance. Normally, the launch pad must be cleared during the time that destruct ordnance is being electrically connected or disconnected. This includes evacuation of the complete erector and the White Room which encapsulates the spacecraft.

One of the requirements after a scrub is to electrically disconnect this ordnance. Again, through the cooperation of Range Safety, a procedure was worked out whereby this could be done simultaneously with other pad operations. This resulted in a net saving of approximately thirty minutes during recycle.

Simultaneous Launch Countdown

The problems associated with planning, coordinating, writing, and performing a launch countdown are sizeable. Moreover, the enormity of the complexities involved in a simultaneous rendezvous launch countdown are many times greater by comparison.

Simultaneous rendezvous launch countdown may be defined as one single countdown which integrates the various countdowns of many agencies and results in the launch of a target vehicle followed by a manned spacecraft. In this case, the target vehicle is an Agena and the spacecraft is a Gemini and their launches are separated by one revolution. The simultaneous launch countdown utilized on the Gemini program is actually a combination and integration of many countdowns from many agencies.

To deal with the conflicts involved and the coordination required to integrate these documents, the Gemini Rendezvous Mission Countdown Group was organized as a subcommittee of the Gemini Launch Operations Committee (GLOC).

The group was chaired by NASA (Florida Operations) and the agencies represented were:

1. NASA Goddard Space Flight Center
2. NASA Mission Control Center (Cape)
3. NASA Mission Control Center (Houston)
4. NASA Gemini Program Office
5. NASA Flight Crew Operations Division
6. Air Force Eastern Test Range
7. Air Force 6555th Aerospace Test Wing
8. Aerospace Corporation
9. Martin Company
10. McDonnell Aircraft Corporation

11. General Dynamics/Astronautics

12. Lockheed Missiles and Space Corporation

13. General Electric Company

14. Burroughs Corporation

15. Pan American World Airways.

The first meeting of this group was in March 1964.

Assumptions

From the outset, certain basic assumptions had to be made if a simultaneous launch countdown were to be possible without major hardware changes.

RF Interference. The additional RF resulting from a dual countdown was considered as a possible source of interfering frequencies (Figure 1). Fortunately, all this RF did not radiate simultaneously which simplified the situation.

For prior-to-launch testing, the received frequency considered of importance was the command frequency used for both Range Safety and the Digital Control System (DCS) in both Gemini and Agena. An analysis was performed at the Martin Company in Baltimore to determine the possibility of the combination frequencies, fundamentals, and second harmonics falling within the receivers' operating or image band widths. Approximately 600 combinations were considered and none fell within the interfering band widths for the receivers.

Since the command frequency is common for the Gemini spacecraft DCS, Gemini launch vehicle flight termination system, and Agena target vehicle command control system, strict operating procedures among complexes, the Range transmitter, and Houston were instituted.

Propellant Operations. Certain activities involving the toxic propellants of the Gemini launch vehicle restrict operations elsewhere. For instance, when the airborne tanks are brought to flight pressure in the combined count, a 7000 foot radius around launch complex 19 must be cleared. This presented a problem to operations on Complex 14 (Atlas-Agena), Complex 16 (astronaut trailer), and some of the nearby camera and tracking sites.

A waiver was granted in the case of Complex 14 and only a limited number of personnel was allowed in the other areas. Also, the time of pressurization was moved to better fit surrounding activities.

Agena Launch Time

A detailed orbit and mission analysis indicated that in no case could the Gemini launch ever take place less than 95 minutes after the Agena launch. This considered all possible dispersions for any acceptable Agena orbit.

T-95 minutes was selected as the Agena launch time since it was minimal. However, the nominal time for Gemini launch was approximately 100 minutes following the Agena liftoff. This meant that a built-in hold of approximately five minutes late in the count was required to adjust for the precise Gemini launch time. This time would be determined by NASA computers after an analysis of the Agena orbit. T-3 minutes was picked as the best time for this hold since it is the latest all the Gemini systems can hold without being committed to launch, and it is also the time when the guidance computer transmits the exact launch azimuth to the GLV.

Gemini 3 Countdown

As early as the first manned Gemini flight (Gemini 3), the Gemini Launch Vehicle countdown was being modified to incorporate changes which would be required for a rendezvous mission. Some of the modifications to that countdown included:

1. The rearrangement of major testing so that a high degree of confidence had been attained by about T-100 minutes,

the time of astronaut entry into the spacecraft and the approximate time of Agena launch;

- Establishment of the period between T-190 minutes and T-175 minutes as the time when destruct ordnance would be electrically connected on the Gemini Launch Vehicle. This not only required all RF to be silent on Complex 19, but also necessitated the Range command transmitter to be off;

3. The time of the final closed loop Guidance Command Test (GCT) was set at T-60 minutes. It was felt that this was the earliest that the Burroughs computer could support this test because of the turnaround required after the Atlas launch.

Gemini 4 Countdown

The evolution of the simultaneous rendezvous countdown continued with a major procedural change which was written into the GLV-4 countdown. This modification was the division of the count into two separate parts - one run the day prior to launch (F-1), and the other starting at T-240 minutes on launch day. The portion run on F-1 day included most of the major interface testing among the Gemini launch vehicle, the spacecraft, and the guidance ground station. This was done in order to (1) provide a greater margin of assurance that the critical Gemini systems were good prior to the time the Agena count would normally start (T-530 minutes) and (2) to shorten the Gemini Launch Vehicle count on launch day from 420 minutes to 240 minutes. The purpose of this abbreviation was to allow propellant loading of the launch vehicle to take place later, thereby decreasing the propellant heat rise prior to launch.

Gemini 5 Countdown

There were no major modifications to the GLV-5 countdown; however, valuable experience was gained and very profitable lessons were learned.

Simultaneous Launch Demonstration (SLD). A full-blown practice of a simultaneous rendezvous launch countdown was performed in July 1965. The test objectives were as follows:

1. To demonstrate the operational capability and readiness of Complex 19 and Complex 14 to support a simultaneous launch countdown for a rendezvous mission;

2. To verify the capability of the guidance ground station and computer to support launches on 95 minute centers;

3. To verify the capability of the Burroughs guidance computer to support Mission Control Center Houston (MCCH) and Goddard Spaceflight Center countdown activities simultaneously with Complex 19 and Complex 14 launch operations;

4. To verify that all operational command communications channels functioned properly;

5. To demonstrate the capability of all program documentation to support simultaneous operations;

6. To provide and establish operational procedures for the Gemini 6 simultaneous launch countdown;

7. To provide each participating agency training and experience in a simultaneous countdown and to improve operational proficiency;

8. To verify compatibility of Complex 19/Complex 14/Eastern Test Range (ETR) RF radiation scheduling;

9. To verify the capability of ETR to support launches on 95 minute centers;

10. To verify the capability of Mission Control Center (Cape) to transmit Atlas/Agena and Gemini/Titan data to MCCH and accommodate communication network requirements.

All operations normally performed in the launch count were done in the SLD except ordnance loading and engine start sequences.

All test objectives were met and only some minor operational and coordination procedures required changing.

Gemini 6 Countdown

No major changes were made in the Gemini 6 countdown as a result of the Gemini 5 SLD or Gemini 6 SLD.

The culmination of over eighteen months of planning and coordination occurred in October 1965 when a perfect no-hold simultaneous rendezvous countdown was performed down to T-42 minutes when the mission was terminated due to an Agena flight failure.

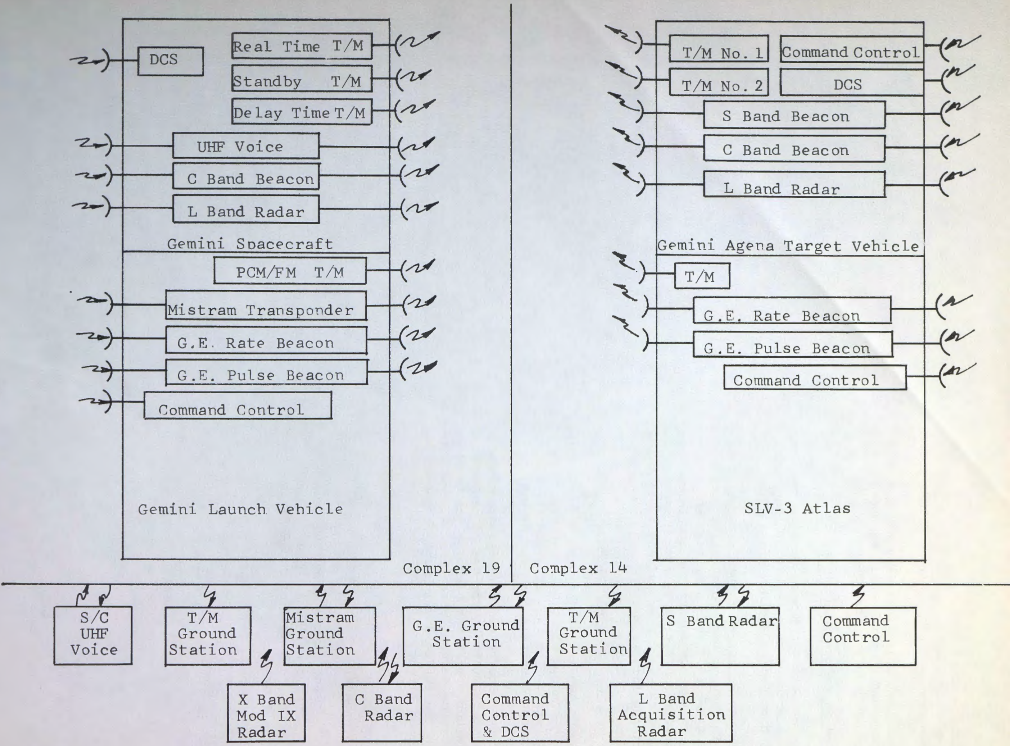
Conclusion

Space rendezvous has been accomplished. The concept of recycle has been demonstrated. The idea of a concurrent launch countdown has been proven.

These occurrences were made possible, in part, through the use of rendezvous launch operations planning, an unknown science several years ago but now a key in the future development of manned space flight.

Reference:

[1] "Testing the Man-Rated Launch Vehicle", F. X. Carey, Third Space Congress, Cocoa Beach, Florida



Range Support RF
Figure 1 - Dual Countdown RF Environment