ATS-6 FLIGHT ACCELEROMETERS

Roger Mattson, George Honeycutt, and Fred Lindner
NASA Goddard Space Flight Center

HISTORY AND OBJECTIVES

At the inception of the Applications Technology Satellite (ATS) program, two flight spacecraft, ATS-F and ATS-G were scheduled to be launched on two Titan III-C launch vehicles. This was the first time a NASA unmanned spacecraft was to be launched on this vehicle and it was deemed necessary to acquire flight data regarding payload environment.

A study of the types of instrumentation that would be applicable was performed by the ATS Project Office. The review consisted of defining the type of instrumentation such as accelerometers, strain gages, and acoustic microphones, and the mode for using such instrumentation as well as methods of transmitting the acquired data to the ground stations. The purpose for flying the instrumentation was as follows:

1. Provide data for verifying basic spacecraft mode shapes and frequencies during powered flight while attached to the Titan III-C vehicle. Data was to be used to update and revise the structural analytic model of the ATS-F and -G spacecraft.
2. Provide failure mode detection and diagnostic information on in-flight anomalies.
3. Provide data that could be used in the design of future spacecraft flying on the Titan III-C.

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As a result of the ATS-F project study, the accelerometer system shown in Figures 1 and 2 was baselined and selected for the ATS-F spacecraft. Basically the NASA Project Office was responsible for providing the accelerometers to be mounted on the spacecraft as well as one accelerometer mounted on the transtage interface ring at the adapter interface with the spacecraft. The launch vehicle contractor provided the necessary interface wiring between these instrumentation points, the signal conditioning equipment and a means for telemetering the data through the vehicle telemetry system to the ground stations.

As the program progressed and ATS-F operational requirements were reviewed, it became apparent that the accelerometers mounted to the spacecraft hub would provide a valuable source of data for indicating when the spacecraft had been separated from the transtage. Since the data from these instruments was passed through an in-flight disconnect at the separation plane between the transtage and ATS-F, the moment this connector was broken the signal to the telemetry system would show a step function change. By monitoring these telemetry traces on the ground at the appropriate times during flight sequences, a positive indication of spacecraft separation could be provided. Since the ATS-F had no other positive (direct) means for indicating separation, this particular data source was extremely valuable for subsequent operational plans.

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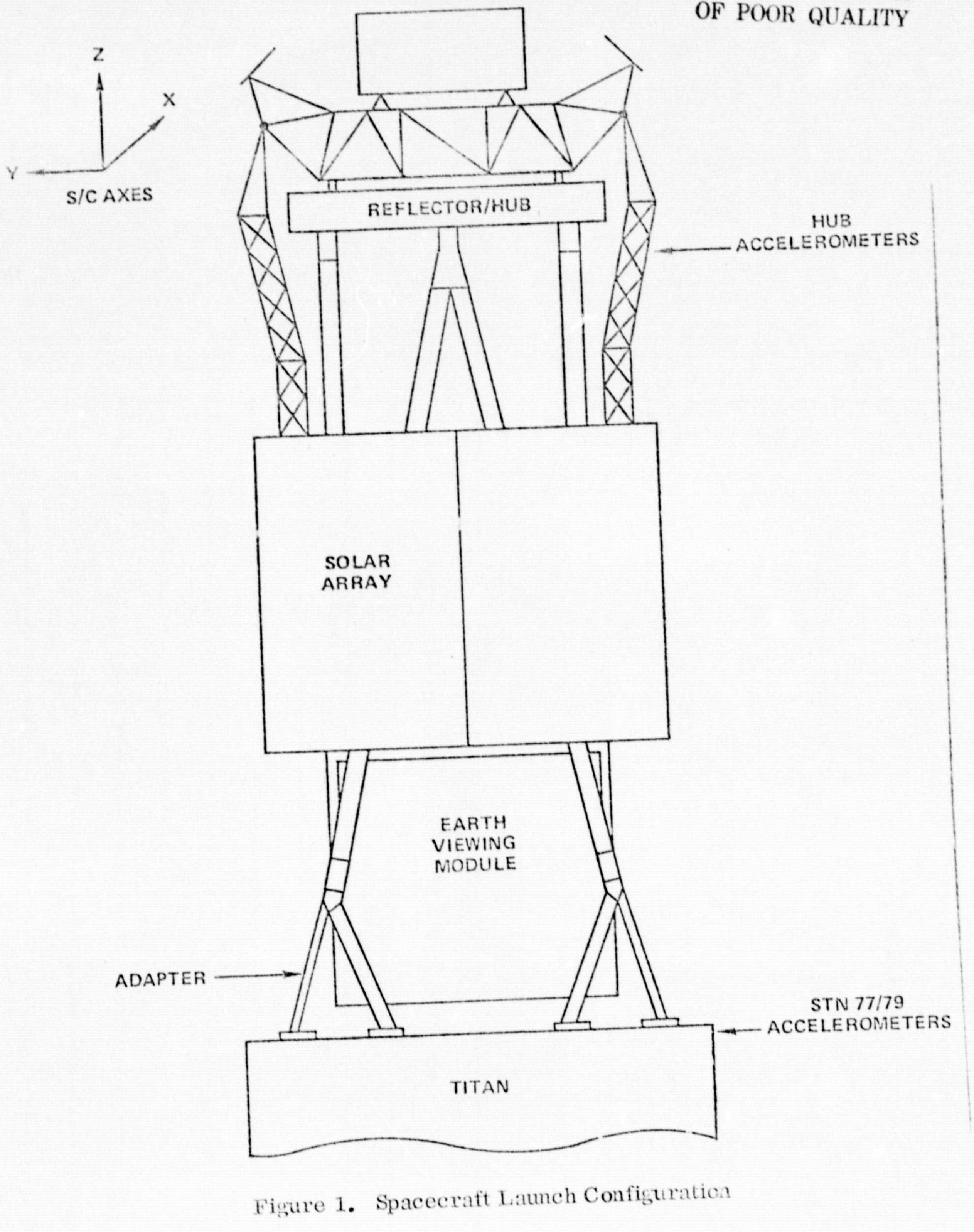

Figure 1. Spacecraft Launch Configuration

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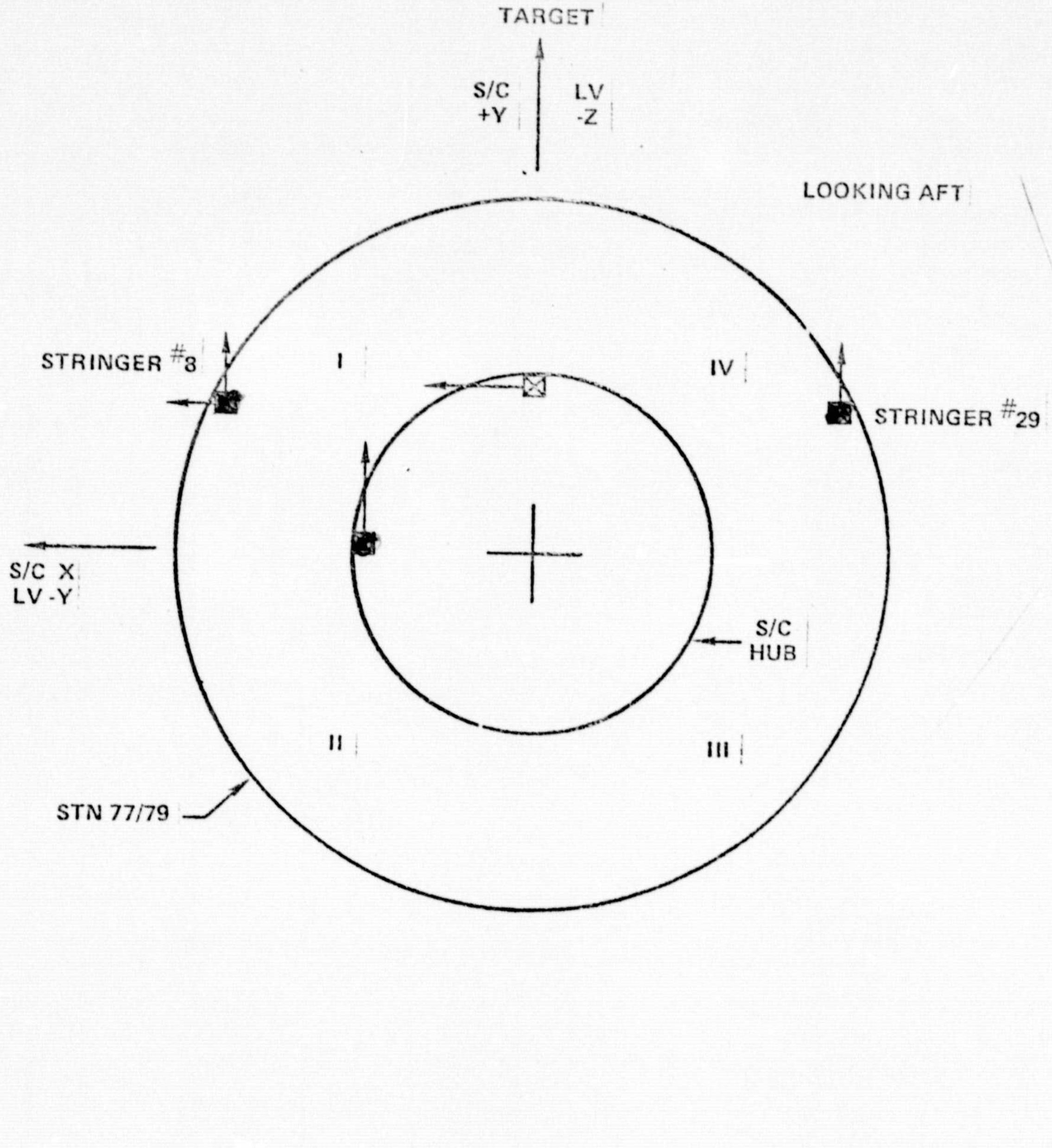

Figure 2. Axes Definition and Accelerometer Location

SYSTEM DESCRIPTION

Accelerometer Description and Location

Five accelerometers were mounted on the launch vehicle near the adapter base and three on the spacecraft hub. Table 1 lists the accelerometers with their description and Figure 1 shows their relative locations.

Data Acquisition System

The signals from these transducers were conditioned and transmitted via the Titan launch vehicle S-band telemetry system. This data was recorded by appropriate ground stations and magnetic tape copies sent to Goddard Space Flight Center (GSFC). These were then decommutated to a format compatible with GSFC analysis equipment. The data was reduced to filtered oscillograph time histories for analysis.

FLIGHT RESULTS

Interface Data

The flight data was analyzed to obtain response at the interface and at the top of the spacecraft (hub). Table 2 presents a summary of the vibration response data for significant launch events at the interface between the ATS-F spacecraft and the Titan III-C vehicle. Note that this is the vibration response only with no steady-state acceleration. This data was taken from oscillograph records and the dominant frequency listed is approximate. These results are averaged responses of the accelerometer located at stations 77 and 79.

Table 1

Accelerometer Reference Data

Accelerometer Number	Type	Location	Coordinates		Range (g)
			Spacecraft	Titan	
2328	Gulton - Servonics Model LA 120204A	Station 79 Stringer 8 (Quad I)	Z	X	+7.5 -2.5
2329	Gulton - Servonics Model LA 120204A	Station 77 Stringer 8 (Quad I)	X	Y	±2.5
2330	Gulton - Servonics Model LA 120204A	Station 77 Stringer 8 (Quad I)	Y	Z	±2.5
2414	Gulton - Servonics Model LA 120204A	Station 79 Stringer 29 (Quad IV)	Z	X	±2.5
2349	Statham Amplibridge Model A404TC-4	Station 79 Stringer 29 (Quad IV)	Y	Z	±4.0
2350	Statham Amplibridge Model A401TC-25	Spacecraft Hub	Z	X	±25.0
2351A	Statham Amplibridge Model A401TC-25	Spacecraft Hub	X	Y	±25.0
2352	Statham Amplibridge Model A401TC-10	Spacecraft Hub	Y	Z	±10.0

Table 2

Dominant Dynamic Response (<80 Hz)
at Spacecraft-Vehicle Interface for
Significant Launch Events

Event	X(Y)		Y(Z)		Z(X)	
	Accel.	Freq. (Hz)	Accel.	Freq. (Hz)	Accel.	Freq. (Hz)
Liftoff	0.4	45	0.3 1.3 2.3	12 30 70	0.4 0.7	5 45
Stage I Shutdown	0.1 0.4 1.0	10 30 70	0.5	30	0.4 0.5	20 50
Stage II Shutdown	0.9	40	0.4 0.6	40 70	0.2 0.4	20 40
Stage III Second Start	0.8	40	0.2 0.3	20 40	0.4	40
Stage III Second Shutdown	0.4 0.5	40 70	0.1 0.5	20 40	0.6	40

Spacecraft Data

Table 3 is a summary of the response measured at the top of the spacecraft or hub area for significant launch events. This data has been filtered through a narrow band filter as shown at the bottom of the table. The frequencies listed are the lateral fundamental nodes of the spacecraft (8.5 Hz) and the first longitudinal node (36 Hz). Also shown on this table is the maximum steady-state acceleration reached for each event.

Predicted Versus Measured Data

Table 4 is a presentation of the maximum measured spacecraft response compared with the mean +2 sigma calculated values. These measured numbers are simple peaks picked off the oscillograph plots without any filtering and the predicted data came from the flight loads analysis. Note that in general the predicted was higher then measured, as expected, since it is mean +2 sigma. The exception to this is the Z-axis, stage III, second start, showing that measured data exceeded predicted. The predictions for this event had less statistical base of flight data, thus perhaps has more error. Also the stage III on this flight could have been more rough than previous. Note that there were no predictions for liftoff or stage III second shutdown. These were omitted from the program because it was believed, based on previous Titan III-C flights, that these events were less severe than the others, and because of costs constraints on the ATS-F program. As it turned out the liftoff event was the most severe for lateral Y-axis response. This was definitely unexpected and the reasons for it are not fully understood.

Table 3

Response at Top of ATS-6 Spacecraft During Significant Launch Events

Event	ATS-6 Axis	Freq. (Hz)	Filtered* Vibration Response (±Peak G)	Steady State Acceleration
Liftoff	X	8.5	0.2	-0.8
	Y	8.5	2.4	
	Y	36.0	1.1	
Stage I Shutdown	X	8.5	1.4	
	Y	8.5	0.4	
	Z	36.0	0.4	+3.9
Stage II Shutdown	X	8.5	0.3	
	Y	8.5	0.2	
	Z	36.0	1.1	+2.3
Stage III Second Start	X	8.5	0.4	
	Y	8.5	0.2	
	Z	36.0	0.5	-1.3
Stage III Second Shutdown	X	8.5	0.3	
	Y	8.5	0.2	
	Z	36.0	0.8	+2.0

* 25 - 45 Hz Filter for Z
0 - 12.5 Hz Filter for X and Y.

Table 4

Predicted Versus Measured Data

Event	Axis	Measured (Max. g)	Predicted (Mean +2 sigma)
Liftoff	X	0.2	
	Y	2.4	
	Z	-1.1	
Stage I Shutdown	X	1.4	2.5
	Y	0.4	1.4
	Z	-4.5	-4.6
Stage II Shutdown	X	0.3	0.7
	Y	0.2	0.4
	Z	-3.6	-4.6
Stage III Second Start	X	0.4	0.5
	Y	0.2	0.7
	Z	-2.1	-1.8
Stage III Second Shutdown	X	0.3	
	Y	0.2	
	Z	-2.4	

Separation Data

Positive indication of spacecraft separation from the launch vehicle was verified by consulting real-time flight accelerometer data. Shortly after the separation, pyrotechnic devices were actuated and the separation springs caused relative movement between the spacecraft and launch vehicle. This took up slack in the transducer cable and severed the fly-away connector. When this event occurred there was an immediate data dropout from the spacecraft accelerometers and thus an indication of separation.

CONCLUSIONS

The prime objectives justifying the need for instrumenting the ATS-F flight were realized. Upon receipt of the flight data and its subsequent analysis, the following results were attained:

1. Spacecraft/launch vehicle separation was indicated
2. Verification that the mathematical techniques used in the loads analysis were adequate in predicting predominant frequencies and associated magnitudes
3. Valuable data for the design of future spacecraft to be launched by Titan III-C were acquired.