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AN INVESTIGATION OF PRE-LAUNCH AND IN-FLIGHT STS RANGE SAFETY RADIO SIGNAL DEGRADATION AND DROPOUT

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I. Introduction to the Shuttle Range Safety System (SRSS).

The term, "Range Safety", in this report refers to the need and responsibility to assure protection of the population and property in the environs of the launch areas of the Air Force Eastern Test Range (AFETR) and along the trajectory of the vehicles in flight. Included in the AFETR are the two launch complexes, pads 39A and 39B, at the Kennedy Space Center (KSC) from which shuttle launches occur. The term , "Shuttle Range Safety", refers specifically to range safety concerns surrounding the launches of the Space Transportation System (STS) vehicle, or "Shuttle" as it is commonly identified.

An individual at the AFETR charged with the responsibility of assuring range safety is the Range Safety Officer (RSO). The RSO is employed by the AFETR and is thus not an employee of the National Aeronautics and Space Administration (NASA). The RSO has the important responsibility of sending a command to destroy any launched vehicle which errs sufficiently from a planned flight trajectory as to present a hazard to population or property. The destruct command is sent in the form of an encoded radio signal from one of several range safety transmitters included in the AFETR to receiving antennas onboard the vehicle.

The range safety system (RSS) transmitters operate at a frequency of 416.500 MHz. The transmitting antennas transmit left circularly polarized waves, and the shuttle range safety system (SRSS) receiving antennas onboard the shuttle vehicle receive left circular polarization.

The shuttle vehicle consists of the orbiter, which carries the crew and payload, two solid rocket boosters (SRB's), and the external tank (ET) which contains the hydrogen and oxygen fuel burned by the orbiter's three main engines. A total of six range safety receiving antennas are positioned on the shuttle vehicle. This includes two on the left SRB, two on the right SRB, and two on the ET.

In addition to the Cape range safety transmitter facility, other tracking and range safety transmitter systems currently used by the AFETR are based at (a) the Jonathan Dickson site, approximately 100 miles south and 30 miles east of the Cape site, (b) the Bermuda island site, and (c) a site at Wallops Island, Virginia. Particular characteristics of the four currently-used transmitter facilities are summarized in Table I.

TABLE I. Characteristics of AFETR Range Safety Transmitter Facilities.

	Cape	Jonathan Dickson	Wallops	Bermuda
Power	*	69 dBm (8 kw)	60 dBm (1 kw)	69 dBm (8 kw)
Ant. Gain	*	22 dB	18 dB	18 dB
Altitude	21.8 meters	12.3 meters	14.9 meters	19.8 meters
Latitude	28.4394^{o} N	26.6550^{o} N	37.8665^{o} N	32.3480^{o} N
Longitude	80.5983^{o} W	80.1080^{o} W	75.5050^{o} W	64.6535^{o} W

The asterisk appearing in Table I under the Cape transmitter site is to indicate that a combination of transmitting capabilities exists at that site. The Cape transmitter site has two omni antennas and two 18-dB gain steerable antennas. It also has a low-power transmitter (about 600-700 watts, nominal) and another for high-power transmission (8 kw, nominal). Normal procedures for shuttle launches are for the Cape site to transmit on high-power from an omni antenna.

Range safety depends upon maintaining a sufficiently high power input to the integrated receiver-decoders (IRDs) onboard the two SRBs and the ET. This study focused on observed fades or dropouts of signal levels to some of the IRDs on some flights both while the vehicle was on the launchpad and during flight. This study is limited to those shuttle flights that have occurred from STS-26 through STS-40.

II. Analysis of Signal Level Fluctuations

Any analysis of range safety signal behavior begins at the launchpads. Table II illustrates the history of background signal levels on the launchpads at the various IRDs mounted on the vehicle. The power levels are expressed in units of dBm (decibels relative to one milliwatt). An observed anomaly observed in this data is that the power level at the pad 39A is persistently lower than at pad 39B, despite being somewhat closer to the transmitter. This is being interpretated as due to a destructive interference contribution in the transmitter illumination of the pad by reflections from reflecting surfaces in the vicinity, a condition which does prevail at pad 39B because of a different geometry.

Table II. **Background Signal Levels at T-600 Seconds**

STS	Launch Date	Pad	LHA (dBm)	LHB (dBm)	RHA (dBm)	RHB (dBm)	ET (dBm)
26	9/29/89	B	-47	-46	-48	-45	-61
27	12/02/88	B	-48	-42	-49	-47	-58
29	3/13/89	B	-47	-45	-48	-47	-56
30	5/04/89	B	-46	-40	-46	-45	-55
28	8/08/89	B	-45	-40	-46	-44	-56
34	10/18/89	B	-46	-45	-47	-49	-60
33*	**11/22/89**	**B**	**-60**	**-56**	**-59**	**-60**	**-68**
32	1/10/90	(A)	(-58)	(-62)	(-55)	(-56)	(-58)
36	2/28/90	(A)	(-58)	(-60)	(-52)	(-53)	(-53)
31	4/24/90	B	-50	-50	-49	-50	-59
41	10/06/90	B	-46	-44	-47	-47	-60
38	11/15/90	(A)	(-55)	(-64)	(-52)	(-52)	(-55)
35	12/02/90	B	-42	-44	-47	-45	-62
37	4/05/91	B	-48	-46	-48	-49	-63
39	4/28/91	(A)	(-58)	(-58)	(-51)	(-52)	(-56)
40	6/05/91	B	-48	-46	-48	-45	-60

Fluctuations of IRD power levels during the countdown before launch are attributable to the retraction motions of two major launch tower appendages, the orbiter access arm and the vent gas recovery system arm (the "beanie cap"). Reflections from the moving surfaces into the SRSS antennas cause signal fluctuations during the motions. Also the stowage positioning of the appendages at the conclusion of their motion can be the cause for a shifting up or down in the background power levels into the IRDs.

During the flights of the shuttle, several types of IRD signal fluctuations have been noted in the flight data and treated. These include: (a) a very rapid fluctuation observed in the ET data during the roll-pitch maneuver which the shuttle undergoes from about 7 to 20 seconds after liftoff, (b) a drop in the signal level to both right SRB receivers of about 20 to 30 dB during the roll-pitch maneuver, (c) a marked further degradation of the right SRB receiver signal levels starting at about 80 seconds into the flight (most noticeable on launches into high-inclination orbits), (d) a general pattern of longer-period fluctuations in both the SRB and ET receiver data after the roll-pitch maneuver, and (e) after SRB separation, ET signal variations of slow modulated variation superimposed on a motonically decreasing background.

The rapid ET signal fluctuations (a) are directly attributable to two causes. The first is the rapid phasing interference to be expected by the motions of the two ET antennas as the vehicle rolls through an angle in excess of 90 degrees in less than 15 seconds. During most of the roll the A antenna is moving away from the transmitting antenna while the B antenna is rolling around in the direction toward the transmitting antenna. Thus, the wave path to the A antenna is increasing while the wave path to the B antenna is decreasing, hence the rapid phasing interference. A second contribution to the rapid ET signal fluctuations during the roll is attributable to the structure in the roll-axis ET antenna pattern.

The signal level drop (b) comes about because the two right SRB antennas rotate around into the "shadow" of the shuttle, thus experiencing a diminished input power. The right SRB receiver signal fading (c) is due to increasing attenuation by the SRB plume as the vehicle's aspect, as viewed from the transmitter, becomes a tail-end view.

The general pattern of longer-period fluctuations (d) after the roll-pitch maneuver in both the ET and SRB receiver data before SRB separation are probably due to (1) slow phasing interference effects caused by changes in total wave propagation paths into the pair of antennas on an SRB or the ET as the vehicle moves along its trajectory, slowly changing its aspect with respect to the Cape transmitter, and (2) SRSS antenna pattern variations.

The slow modulated fluctuations in the ET data after SRB separation (e) can be explained. The monotonically decreasing background is a natural space loss drop due to increasing distance from transmitter to ET antennas, while the modulated variations are almost certainly due to SRSS antenna pattern fluctuations.

Preliminary explanations have been proposed for many of the observed fluctuations in signal levels. It is being recommended that experiments and further investigation be performed to test the validity of certain of the explanations offered in the analysis section. Such will be pursued as a continuation of this summer's investigation.