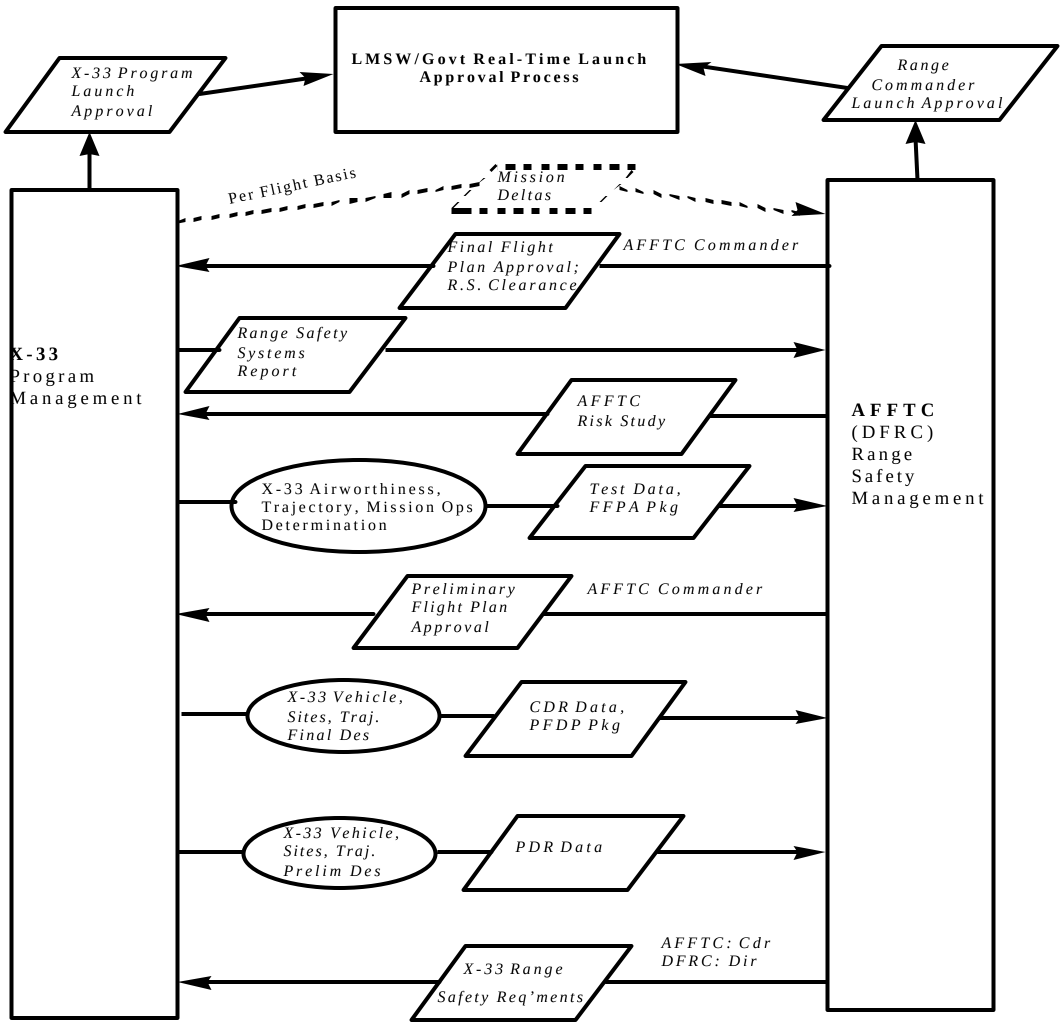
Figure 3.3 RANGE SAFETY LAUNCH APPROVAL PROCESS



The review team was impressed with the rigorous approach the LMSW/USAF team is using to evaluate and mitigate risks, including coordination with FAA and civil authorities. At the same time, the team acknowledged the need to remain vigilant in examining and discussing risks to public safety and the ways in which these risks will be mitigated. LMSW agreed to provide the review team with the complete Flight Safety Analysis (on CD-ROM), including debris contours, for all phases of flight from Haystack to Dugway and Malmstrom.

<u>X-33 Range Safety Requirements Document (RSRD)</u>

This document outlines the Range Safety Program and Range Safety requirements for the X-33 flight test program. It defines responsibilities and authorities and delineates policies, processes, and approvals for all range safety activities from design concept through test, checkout, assembly, launch, flight, and landing. This document has been written to primarily address X-33 flight test requirements as they relate to range safety. Specific requirements for system safety, ground safety, launch complex safety, and related matters are not within the scope of this document. These topics are addressed separately by AFFTC, DFRC, and other applicable directives and processes. Table 3-1 sets out risk acceptability guidelines used in development of the RSRD.

TABLE 3-1: Acceptability Guidelines for Prelaunch Launch Area/Launch Complex Hazard Consequences and Probability Categories

HAZARD SEVERITY	POTENTIAL CONSEQUENCES				PROBABILITY *				
Category	Personnel Illness/Injury	Equipment Loss($)	Unit Downtime	Data Compromise	A	B	C	D	E
I Catastrophic	May cause death.	> 500,000	> 4 months	Data is never recoverable or primary program objectives are lost.					
II Critical	May cause severe injury or severe occupational illness.	100,000 to 500,000	2 weeks to 4 months	May cause repeat of test program.					
III Marginal	May cause minor injury, or minor occupational illness.	1000 to 100,000	1 day to 2 weeks	May cause repeat of test period.					
IV Negligible	Will not result in injury, or occupational illness.	< 1000	< 1 day	May cause repeat of data point, or data may require minor manipulation or computer rerun.					

RISK PRIORITY: Unacceptable Waiver or deviation required Operation permissible

* Refers to the probability that the potential consequence will occur in the life cycle of the system (test/activity/operation). Use the following list to determine the appropriate Risk Level.

	DESCRIPTION**	THRESHOLD LEVEL	PROBABILITY VALUE	SPECIFIC INDIVIDUAL ITEM	FLEET OR INVENTORY***
A	Frequent		$3X10^{-1}$	Likely to occur repeatedly	Continuously experienced
		$8X10^{-2}$			
B	Reasonably probable		$3X10^{-2}$	Likely to occur several times	Will occur frequently
		$8X10^{-3}$			
C	Occasional		$3X10^{-3}$	Likely to occur sometime	Will occur several times
		$8X10^{-4}$			
D	Remote		$3X10^{-4}$	Unlikely to occur, but possible	Unlikely, but can reasonably be expected to occur
		$8X10^{-5}$			
E	Extremely improbable		$3X10^{-5}$	The probability of occurrence cannot be distinguished from zero	Unlikely to occur, but possible

** Definitions of descriptive words may have to be modified based on quantity involved.
*** The size of the fleet or inventory and system life cycle should be defined.

Independent Review Teams (IRT)

Independent review teams comprised of individuals who are knowledgeable and who have no vested interest or decision making role will participate in all critical program pre-launch milestone reviews, such as L-60 day and L-30 day safety and readiness reviews. The Range Safety IRT is co-chaired by the AFFTC-Range Safety Office with support from the NASA/DFRC Operations Office. This IRT provides information to the commander for his final decision to allow the X-33 to launch. Figure 3-4 provides an outline of planned operational reviews.

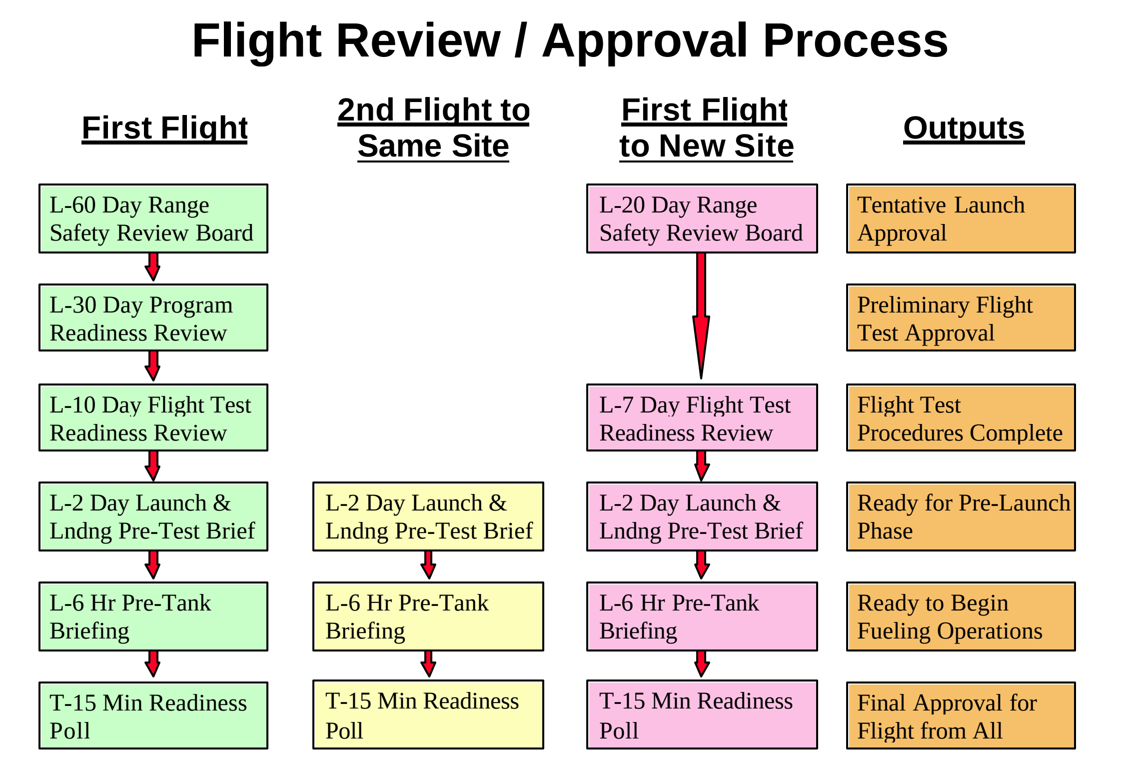


Figure 3.4

3.7 System Safety and Quality Assurance Processes

Emergency Response Plan

The review team noted that the Operational Ground Safety Program, containing the Emergency Response Plan, provided a thorough approach for addressing emergency situations both inside the military test facility as well as down range. The document also provided an excellent mishap investigation plan. Reportedly "lessons learned" from the Clipper Graham mishap contributed to the development of this plan.

Vehicle Turn-Around and Maintenance

The review team noted that the LMSW intends to deploy "aircraft-style" maintenance practices which involve a second set of eyes to verify configuration of all vehicle maintenance activities. Written instructions and sign-off documentation (validation) are in place for all maintenance procedures. Again it was noted that "lessons learned" from the DC-XA, Clipper Graham test-flight, landing mishap were considered in developing these assurance measures.

3.8 Software Independent Verification & Validation (IV&V) Process

Discussions with LMSW software experts during the on-site review resulted in an agreement to provide the MSFC SMA representative with updated, hardware and software testing requirements for systems and subsystems. LMSW agreed that system level testing shall be accomplished using flight software. LMSW agreed that all updated test plans will emphasize the requirement to test using the flight software.

Software Availability for Integrated Systems Testing

It is recognized that software development is behind schedule. Thus concerns exist that these delays will make it difficult to implement integrated ground testing of systems such as the engine controller which uses software-driven risk mitigation capabilities (e.g., cross-functional turbo-pump capability to use a single pump to serve both engines in the event of a failure).

NASA IV&V Support to X-33

Allied Signal and LMSW are the principal developers of the X-33 software. The NASA IV&V facility in Fairmont initiated support to the X-33 program in November of 1997. The Fairmont level of effort is estimated to represent 10 person-years in 1998 and 10 person-years in 1999. Even though the IV&V support is provided under a task order agreement to LMSW, NASA will be able to assert a greater level of insight by virtue of this arrangement.

Pre-and Post-Flight Certification Process

The pre-and post-operating procedures define the process for test, review, approval, and implementation of configuration changes to the ground and flight software. Launch "I-Loads" will be verified prior to each flight by the Integrated Test Facility. The review team software analyst and LMSW software managers also discussed the extent to which end-to-end verification and validation will be conducted (flight and ground software) between each flight of the X-33. The review team feels that this is an issue worthy of further assessment by the NASA X-33, SMA support.

4.0 Safety of Flight Issues

Worst case scenarios for risk exposure are associated with either: 1) a catastrophic, in-flight failure event, explosion, or breakup of the vehicle, or 2) initiation of the FTS in response to anomalous flight trajectory.

The metric employed in range safety analysis is the Expected Casualty (Ec) probability. The range safety criteria is 30 in 1 million (30 x 10 ^ (-6). Scenario 1 has a higher probability of causing casualties than Scenario 2 because of the extent of the debris created in a catastrophic event (estimated at over 1000 individual pieces of debris). Scenario 2 assumes a ballistic trajectory of an intact vehicle, initiated by the FTS involving “hard over” commands to both body control surfaces. Safety of flight analyses utilize Scenario 1 (worst case) to bound the maximum expected casualty event. The Ec value for Scenario 1 is 5.0 x 10 ^ (-6) for flight to Michael Army Air Field in Utah and 5.5 x 10 ^ (-6) for flight to Malmstrom Air Force Base in Montana. Both estimates meet the range safety criteria of 30 x 10 ^ (-6) for Ec.

4.1 Powered Flight On-Trajectory Explosion Failures

The X-33 Environmental Impact Statement (EIS) used a projected failure rate of 1/250, “derived from 220 seconds of powered flight” from consideration of the flight records of Atlas, Delta, Titan II, and Space Shuttle LOX-LH2 engines. The EIS used a projected failure probability of 1/6823 for non-powered (or coast) flight. This estimate is based on engineering reliability analysis of component failure data and degree of redundancy.

While vehicle reliability is a central Mission Assurance issue, the ultimate public safety risk mitigator is the Flight Termination System (FTS) which is designed to bring the vehicle down intact within the range safety limits.

4.2 Flight Termination System (FTS)

<u>FTS Overview</u>

Command Receiver Decoder (CRD) receives signal, decodes signal, and initiates termination function. Ground-based Command Transmitter System (CTS) generates, modulates, and transmits the signal. Differences between secure and non-secure systems involve: 1) destruct command generation in the CTS and 2) decoding of the destruct command on-board the vehicle. The IG indicated that a cost increase on the order of $85K to $120K would be associated with implementation of secure system hardware. Additional costs would be associated with program compliance with security control and handling requirements.

Failure to Secure Control of FTS Command Uplink

The NASA Inspector General (IG) has recommended implementation of a high security FTS command/destruct decoder-initiator system and an equally secure command uplink system. Tampering, spoofing or other intentional interference with the FTS could result in destruction of the vehicle during nominal operation or impairment of range safety's ability to terminate flight in the case of an errant ground track. FTS security issues and the perceived need for special security measures are under the authority of the EAFB Commander and Range Safety officials. In discussions with both the IG investigators (at NASA Headquarters) and the Range Safety officials, during the on-site review, it became apparent that a fundamental difference of opinion exists concerning the existence of a credible security threat to operations on the California/Utah/Montana test range.

Resolution

The review team and the X-33 team mutually acknowledged that additional mitigation measures (i.e., secure FTS system deployment) would be appropriate if a credible threat was present. The NASA SMA team took the action to facilitate direct communication between the IG team and the EAFB Range Safety Director to resolve the issue.

4.3 FTS Failure Modes/Reliability

The program is designed to contain Ec well below the required 30 x 10^(-6). The current estimate is on the order of 5 or 6 x 10^(-6). If the FTS fails to operate properly, the risk management process will have failed and risk exposure will be unlimited, as is the case with the Space Shuttle, Titan IV and other similar space flight launch systems. The FTS reliability and failure modes must be carefully evaluated and risk mitigation strategies verified. It is understood that the Range Safety Independent Review Team (IRT) will provide a measure of verification. However, the review team believes that it would be appropriate for NASA SMA to closely monitor this activity.

4.4 FTS Redundancy

It was noted that the Utah Test and Training Range (Dugway Proving Grounds) personnel do not believe that the current X-33 FTS configuration is fully redundant. This is an open issue which needs follow-up. The review team acknowledged the importance of attaining a full understanding of FTS reliability, failure modes, and failure mitigation.

4.5 Other Information Security Issues

In response to another IG recommendation, the LMSW indicated that they are implementing a program-wide information security analysis and risk mitigation activity.

5.0 Mission Assurance Issues

5.1 Scaled-Back Incremental Flight Demonstration Approach

The X-33 Final Environmental Impact Statement (EIS) (section ES.5) discusses risk mitigation of potential flight safety impacts: "Potential flight safety impacts would be mitigated by careful selection of flight corridors and cautious implementation of the flight test program through incremental expansion of the flight envelope (progressively increasing altitude, speed, and distance."

As discussed in Section 2.0 of this report, the original flight program consisted of flights to Silurian, Dugway, and Malmstrom. The review team expressed concern that the incremental risk management approach outlined in the Final EIS was being discarded with the elimination of flights to Siluarian.

On-site discussions with LMSW indicated that the Silurian site was being eliminated from the program on the basis of flight operational risk management concerns including requirements for a "high-g" approach maneuver, a negative "g" condition at Main Engine Cut Off (MECO) risking pump cavitation or other engine damage, and requirements for modifications to pressurization systems to accommodate the short flight. It was stated that "a short Silurian trajectory is too brief to compensate for first flight performance and navigation uncertainties." In addition, LMSW presented information showing continued adherence to careful incremental increases in speed, altitude, and heating effects, consistent with traditional X-vehicle flight testing risk management.

5.2 Other Mission Assurance Issues

A myriad of technical issues exist in the X-33 program. The recent X-33 CDR identified the following "High" and "Medium" risk management items:

<u>High Risks</u>

- Vehicle Assembly Dependency On Cryo Tank Delivery
- Schedule
- Vehicle Weight - X-33
- Integrated Test Facility (ITF) Model Development
- Hydrogen Tanks - Cost, Schedule, Structure/Integration
- X-33 Engine H2 Inlet Flow Disturbances
- Hydrogen Leakage and Manufacturing
- Engine Reliability - X-33
- Aeroshell - X-33
- X-33 Flight Software
- X-33 Safe Recovery Reliability

- TPS Seal Design Concepts
- Reaction Control System (RCS) Acoustic Vibration Load

Medium Risks

- X-33 Indemnification
- Control Authority At Low Supersonic Mach Number
- Navigation Integration
- Nozzle Ramp Structural Design
- TPS - Carbon/Carbon
- RCS Thrusters; Methane/Gaseous Oxygen (GOX)
- X-33 Antenna Performance
- X-33 Inter-engine Seals
- X-33 Engine Plume Impingement
- X-33 Engine/Vehicle System Integration
- Environmental Impact Statement (EIS) Approval X-33
- Aerospike Thrust Chamber
- X-33 Aerospike Slipstream/Thrust Vector Control Interaction
- Slosh Damping

An in-depth assessment of these issues is beyond the scope of the current SMA review. Because of the potential time demand necessary to understand each of these issues, the decision was made to focus more specifically on safety and SMA management process concerns. The NASA Independent Annual Review (IAR) team will be conducting a "delta" IAR by the end of March, 1998 and is expected to examine these issues in depth. The NASA SMA organization has the responsibility to assure that Mission Assurance risks do not become safety risks while recognizing the parallel responsibility to promote the likelihood of achieving Mission Success through process level reviews. The review team recognized the need for NASA to increase the level of insight on a daily basis, necessary to understand and monitor critical Mission Assurance issues. These issues are discussed more fully in the following two sections of this report.

6.0 Achieving Safety & Mission Assurance Insight

Background

NASA/MSFC SMA has assumed an "arms length" and, in many respects, a "low key" safety and mission assurance role with regard to the X-33 program. This decision has been taken primarily on the basis that the X-programs represent the "new way of doing business" as manifested in the use of the contractual arrangement known as a cooperative agreement (described in detail in Section 2.0). Under this agreement, signed in July 1996, Lockheed-Martin was to assume all liability for mission mishap. In November 1997, legislation (Senate bill S2150) was proposed to make NASA a partner in damage and injury liability associated with any X-33 failure. NASA is now in the potentially vulnerable position of assuming liability with no oversight, very little insight and virtually no ability to affect program changes very late in the program development life cycle (first flight of the X-33 is scheduled for late summer 1999).

6.1 Insight via Program Commitment Agreements

The top level X-33 Program Commitment Agreement (PCA) sets out the ground rules for the X-33 Program. This document, by design, is a short, concise, top level definition of program objectives, budget, and schedule. In the context of reinvention of government, cooperative agreements, turn-key procurements, and other novel contracting vehicles, it is too easy to believe that NASA is no longer responsible for issues such as public safety and assuring that limited resources are spent on programs with reasonable probabilities of achieving mission success.

The review team recommends that the X-33 Phase II PCA, currently in a revision cycle, be modified to include a new paragraph as follows:

> ***Safety and Mission Assurance Insight***
>
> *The NASA Associate Administrator for Safety and Mission Assurance is responsible for maintaining insight into issues affecting flight safety, public safety, and mission success. The Program Manager and Enterprise Associate Administrator remain ultimately responsible for assuring safety and managing program risk.*

6.2 Achieving Insight

The review team concluded that NASA must increase the level of safety insight into the X-33 program in order to better fulfill Agency SMA responsibilities. The team further concluded that the increased insight mechanism must be implemented as soon as possible. Finally the team recognized the need for the insight to be implemented as an independent NASA activity rather than a task order activity controlled by LMSW. The implementation details must be negotiated among MSFC SMA, DFRC SMA, and X-33 program management. It is recommended that the X-33 SMA insight support report directly to the NASA X-33 Program Manager and report on a “dotted-line” basis to the MSFC Director of Safety Reliability and Quality Assurance.

The X-33 SMA insight support should be chartered to have access to any area necessary to assure safety, but must focus immediate attention on the following processes and issues:

- Flight Working Group (FWG)
- System Safety activities
- Debris Impact/Public Safety/Risk Mitigation
- Development of the Launch Approval Document
- FTS failure modes and reliability
- FTS redundancy
- Closure of FMEA-CIL management concerns voiced by MSFC and JSC
- X-33 information security

In addition, the X-33 SMA insight support should draw upon perspectives gleaned from NASA center-based participants in the X-33 program, supporting LMSW through task order agreements. The X-33 SMA insight support should provide continuing visibility to NASA SMA managers (as well as the X-33 program manager) by way of frequent communication.

The review team concludes that expanding NASA SMA insight will enhance the likelihood of mission success and provide assurance that risks to public safety have been appropriately addressed. The increase in SMA insight will also provide the depth of understanding and level of confidence necessary for NASA to support X-33 launch and flight operations.

7.0 Summary and Conclusions

7.1 X-33 Safety and Mission Assurance Processes

The review team found evidence that rigorous safety and risk management processes were being employed by the LMSW throughout the X-33 program.

7.2 NASA Safety and Mission Assurance Insight

The review team recommends that the NASA X-33 Program Manager in consultation with the MSFC Director of Safety, Reliability, Quality Assurance (SRQA) and the DFRC Director of Safety and Mission Assurance, take the following actions:

- Establish a continuing and on-site SMA support function, reporting directly to the NASA X-33 Program Manager, and reporting on a “dotted line” basis to the Director of SRQA at MSFC.

- Establish a supporting infrastructure as necessary to fulfill the insight role and responsibility of this SMA support function.

- Implement these measures as soon as possible.

7.3 X-33 Program Commitment Agreement

The review team recommends that the X-33 Phase II PCA, currently in a revision cycle, be modified to include a new paragraph as follows:

> ***Safety and Mission Assurance Insight***
>
> *The NASA Associate Administrator for Safety and Mission Assurance is responsible for maintaining insight into issues affecting flight safety, public safety, and mission success. The Program Manager and Enterprise Associate Administrator remain ultimately responsible for assuring safety and managing program risk.*

7.4 Safety of Flight Issues

The review team recommends that the NASA SMA insight support personnel:

- Participate in Flight Working Group activities
- Participate in System Safety activities

- Participate in FTS redundancy deliberations and discussions
- Develop an understanding of FTS reliability and failure modes
- Participate in development/implementation of launch approval and Certificate of Flight Worthiness (COFR)

7.5 Conclusion

Implementation of the recommendations outlined above will enhance the likelihood of mission success and provide assurance that risks to public safety have been appropriately addressed. The increase in SMA insight will also provide the depth of understanding and level of confidence necessary for NASA to support X-33 launch and flight operations.

Appendix A

NASA Safety and Mission Assurance Review Team Membership

NASA Headquarters

Frederick D. Gregory
Peggy Evanich
Jim Lloyd
Steve Newman
Steve Wander
Pete Rutledge
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Marshall Space Flight Center

Amanda Harris
Jim Hatfield

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Jim Phelps
Larry Meyers

Appendix B

Aerospace Safety Advisory Panel Report

Memorandum

To: ASAP Members and Consultants

From: ASAP X-33 Group - Richard Blomberg, Ken Englar, George Gleghorn,
Norris Krone, Roger Schaufele

Subject:X-33 Safety Review - 18-19 February 1998 at Palmdale, CA

General

The Aerospace Safety Advisory Panel was invited to attend a Code Q safety review of the X-33 flight test program that was held at the Lockheed Martin "Skunk Work's" Palmdale facility on February 18-19, 1998. In attendance were the ASAP members (as shown above), representatives of Marshall (MSFC), Dryden (DFRC), the Air Force Flight Test Center (AFFTC), the FAA and the Lockheed Martin Skunk Works Corporation (LMSW).

The meeting commenced with a statement of the primary meeting objective by Fred Gregory, which simply stated was to gain a complete understanding of the X-33 program office's safety related risk management and mission assurance process.

The Code Q staff with cooperation of the Dryden Flight Research Center's X-33 flight test manager, developed an excellent agenda for the review which included an extremely comprehensive set of questions ranging from the status of the risk management plan to the methods of documenting and communicating risk information throughout the X-33 project.

Officially the overall management of the program is the responsibility of Lockheed Martin with the NASA Centers acting as "subcontractors" in a government/industry partnership; however, since the final launch authority rests with the government and the government is furnishing approximately 80% of the funding for the program. It is therefore clear that NASA has a significant responsibility to oversee the program. In this regard, MSFC is the designated Lead Center with its functions specified by the NASA Strategic Management Handbook as modified for the special government/industry partnership of the X-33 program. A small MSFC program office is located at the Lockheed Martin Palmdale facility. The office does not presently have a full time S&MA representative, but an agreement was reached at the meeting to add one from MSFC. A Memorandum of Agreement, as yet unsigned, between MSFC and DFRC defines the responsibility of DFRC regarding system safety, range safety, software assurance and, to a limited extent, quality assurance. The NASA Langley Research Center also has a role to perform independent assessments of the concept design, conduct life cycle costs and tradeoff studies, and evaluate the technology benefits to be gained by the X-33 program. It was abundantly clear that Lockheed Martin has a great desire to cooperate and share with the government the responsibility for all safety related aspects of the program. The briefings presented by Lockheed Martin were comprehensive, meaningful and well presented.

The X-33 Vehicle and Flight Program

The X-33 flight program is one element of Phase II of the larger Reusable Launch Vehicle (RLV) effort. The decision to proceed with Phase III - a full-scale operational RLV vehicle – will primarily depend upon the knowledge gained from and success of the X-33 flight tests. Accordingly, the stated goals of the X-33 are: (1) mature the technologies necessary to design and build a single stage to orbit RLV system, (2) assess the ability to operate the system in a rapid turnaround, low-cost (relative to the space shuttle) mode, and (3) reduce the risks for future RLV private investors. The vehicle is fundamentally an uninhabited flying rocket propulsion system that includes the revolutionary "linear aerospike" engine, internal hydrogen and oxygen tanks, flight and propulsion control systems, the command and control vehicle systems (including the flight termination system--FTS), an autonomous INS/GPS navigation and precision landing system, and the landing gear.

The flight test plan calls for a total of 15 flights of a single vehicle. The first five flights will terminate at Michael Army Air Field (at Dugway Proving Grounds in Nevada), and the remaining flights will end at Malmstron AFB (Montana). It was briefed that the first seven flights would be sufficient to attain all of the program objectives if all seven were completely successful. Since this is highly unlikely, there are eight additional flights included in the flight plan. The basic approach is that when the flight test objectives are all achieved, the flights will stop. There is no particular necessity to complete any specific number of flights past the first seven.

The launch site is on the Edwards AFB range at the Haystack Butte Launch Site. The X-33 launch facility is being constructed as part of the program. Since neither Dryden nor Edwards are experienced in vertical rocket launches, personnel from Kennedy and Vandenberg are supporting the X-33 program.

The flight profiles for the tests will initially be through the Air Force Flight Tests Center (AFFTC) test range followed by transits through well established military corridors (sparsely inhabited) that have been used previously by the military for cruise missile tests. The overall responsibility for test safety and public safety lies with the Commander of the AFFTC. The AFFTC and DFRC jointly authored an X-33 Range Safety Requirements Document which by coincidence was delivered to LMSW on February 19, the day of this review. Also, the first part of the Preliminary Flight Data Package was delivered by LMSW with the remainder due on the 28th of the month. The AFFTC Range Safety reply to the data package is due in six months. The data will be used by AFFTC to establish whether or not the flight tests planned will result in probable danger to the public that exceeds reasonable limits. The goal is to have no greater danger than provided by normal day-to-day overflights of civil aircraft.

It is apparent that the program is pursuing a major risk management program that is capable of identifying, characterizing, and mitigating any significant safety risks inherent in the X-33 flights. One significant motivation for reducing the flight risks by all means possible emanates from the decision to build only one vehicle. With the potential to lose over a billion dollars resting on the single vehicle, the large effort being planned for testing, software verification, simulation and comprehensive risk analysis is well justified.

Potential Safety Issues

The X-33 program has an excellent risk mitigation, and failure effects and modes analysis plan. The primary threat to human safety is the loss of control of the vehicle (at any time between the launch and the wheels landing at the recovery site) with a resultant striking of the ground in an inhabited area. The impact area could be large if the vehicle broke into a large number of parts or small if the vehicle remained essentially intact. There were a number of areas that the ASAP group felt were potential safety issues and that were in need of future evaluation and explanation. Posed as questions, these areas are:

1. To achieve its trajectory, the vehicle must be programmed so that its instantaneous impact point (the point where the vehicle would impact the Earth's surface if its thrust were to be instantly terminated) crosses territory outside the Air Force Test range while there is still a substantial amount of propellant remaining. Specifically, it must cross a corridor containing US Highway 395 and California State Highway 53 when about half-way through powered flight. Is there a safety analysis of the potential hazard when flight termination occurs prior to propellant exhaustion(MECO)?
2. The flight termination system on the X-33 merely delivers hard-over surface commands to tumble the vehicle, but does not necessarily destroy the vehicle. This is contrary to current vertical launch rocket vehicles. It leaves open a whole slew of concerns about where does this flying "rock" go, particularly if it has flight control surfaces that are stuck in some position that may still cause the vehicle to fly in some unpredicted, or attitude control thrusters that are bleeding down the propellant tanks to produce a similar unpredictable trajectory. The prediction of IIP for X-33 is more complicated than for a normal rocket launch vehicle. During flight through the corridors to the destination where high mach numbers are attained, what is the IIP and the probability of causing injury or death to individuals on the ground or in aircraft?
3. What are the assurances that the communication links with the vehicle will be effective in the event that range safety officers need to assert control over the vehicle?
4. What are the assurances that there will be no inadvertent impact with the chemical/biological weapons material stored at Dugway located near Michael AAF?
5. Is the Flight Termination System (FTS) adequate to assure fool-proof operation if needed? Is the communication for the FTS activation totally redundant? In the event of a flight control failure, is it possible that the FTS would be unable to tumble the vehicle to cause vehicle destruction?

6. Is there a possibility of confusion or procedural error in the hand-off between the primary operations control center and the moveable operations control center? How does the system design reduce the risk of conflicting inputs or ambiguity in the command authority? Likewise, how will potentially competing inputs be handled when downmoding after an early MECO?
7. What procedures are being employed to assure a secure communications link that has no credible threat of sabotage? Are the communication links planned as secure as the ones used on the Air Force cruise missiles that fly the routes to be used by theX-33? Alternatively, is it definite that a communications compromise with a malicious intent cannot command the vehicle in a way that would compromise safety?
8. How extensive are simulation activities in emulating the actual flight conditions and determining effects of potential mishaps?
9. What is the system safety plan regarding the launch site procedures?

<u>Summary</u>

The obviously strong interaction among the Air Force range safety people, NASA Dryden personnel and the X-33 project (MSFC and LMSW) indicates that significant checks and balances are inherent in the process of developing and approving flight test plans. This should lead to the appropriate identification and mitigation of risks.

The risk management process that was summarized in the briefing by the project appears suitable and capable of identifying, characterizing and mitigating any significant safety risks inherent in the X-33 tests. There was no evidence of shortcuts being taken or any attempts to circumvent prudent safety approaches. As long as the project remains committed to the approaches outlined at the briefing, it should be capable of managing risk to the lowest possible level for an autonomous rocket vehicle with significant technological advances.

<u>Implications for Future ASAP Activities</u>

Since the vehicle is unmanned and there appears to be adequate attention being paid to safety issues, there is no need for a large ASAP involvement in the X-33 Program. However, the Panel should monitor the program activities to understand any safety-related decisions and to be aware of decisions that might impact the design of the future RLV vehicle that is planned to carry humans.

cc: Fred Gregory

Appendix C: Major Program Milestones

	Scheduled	Accomplished
Phase II Award	07/96	07/96
Preliminary Requirements Review	09/96	09/96
Vehicle Preliminary Design Review(PDR)	11/96	11/96
Draft Environmental Impact Statement (EIS)	06/97	07/97
Vehicle Critical Design Review (CDR)	07/97	10/97
EIS Record Of Decision	10/97	11/97
Begin Launch Site Construction	10/97	11/97
X-33 LOX Tank Delivery	02/98	02/98
First LH2 Tank Delivery To Assembly	05/98	
Private Financing Plan In Place	09/98	
First X-33 Engine Test	10/98	
X-33 Flight Engine Deliveries Begin	02/99	
X-33 Roll Out	05/99	
X-33 First Flight	07/99	
RLV Phase III Implementation Decision	10/99	
X-33 Last Flight	12/99	
X-33 Phase II Program Concluded	12/00	