SATELLITE LAUNCHES IN THE PRC: HUGHES

Hughes Space and Communications International, Inc. (Hughes) attempted to launch two communications satellites from the PRC on Long March rockets which exploded before reaching orbit, one in 1992 and one in 1995. Allegations regarding technology transfer arose in connection with failure analysis investigations conducted by Hughes employees in the aftermath of these failed launches. Specifically, in 1992 and 1995, China Great Wall Industry Corporation, a PRC government entity, launched two Hughes satellites manufactured for Australian (Optus B2) and Asian (Apstar 2) customers from a PRC launch facility in Xichang, PRC.

Both satellites were launched on a Long March 2E rocket. In both cases, an explosion occurred after take-off and before separation of the satellite. Hughes investigated the causes of both of these failed launches and determined that the rocket was the cause of the failures.

In the course of the investigations, Hughes communicated technical information regarding the rocket to the PRC that assisted the PRC in improving the Long March 2E rocket. The activities of Hughes employees in connection with the investigation of the failed launch in 1992 resulted in the transmission to the PRC of technical information that appears to have been approved by a U.S. Government representative but not properly licensed. In the case of the 1995 Hughes failure investigation, Hughes employees exported technical information that also was approved by a U.S. Government representative but should not have been authorized for export to the PRC.

In both cases, Hughes disclosed information to the PRC that related to improving the Long March 2E fairing, a portion of the rocket that protects the payload during launch. Such information was outside the scope of the original licenses Hughes obtained from the State and Commerce Departments, respectively, with respect to the export and launch of the Optus B2 and Apstar 2 satellites. Hughes claims that the 1993 Optus B2 failure analysis disclosures were cleared in advance by U.S. Government officials, but neither Hughes nor the pertinent U.S. Government agencies retained records that would substantiate this claim fully.

The lessons learned by the PRC from Hughes during the 1995 Apstar 2 failure investigation are directly applicable to fairings on other rockets, including those used to launch PRC military satellites.

Although the Long March 2E has not been used since 1995, it is possible that the PRC may have transferred the lessons learned from this launch failure investigation to its ballistic missile programs. These lessons could lead to the development of a more reliable fairing for use with advanced payloads on military ballistic missiles.

Hughes obtained a clearance for the 1995 disclosures that was improperly issued by a Commerce Department official. Hughes was confident that the cause of the 1992 launch failure on the PRC's Long March 2E rocket was the fairing. Hughes then ascertained with more certainty that the fairing was responsible for the 1995 launch failure. Hughes required that the PRC take appropriate corrective measures so that future launches of Hughes satellites on the Long March 2E rocket could occur and be insured.

Hughes employees conveyed to the PRC the engineering and design information necessary to identify and remedy the structural deficiencies of the fairing. At the time of the 1992 failure, the export of both the satellite and any information that might improve the rocket were subject to State Department licensing jurisdiction.

Hughes knew that the fairing was part of the rocket and that a State Department license was required to discuss improvements with the PRC. Although Hughes did not have a license to disclose information to the PRC relating to improvement of the fairing, Hughes, nonetheless, made such disclosures. Hughes claims that each disclosure was authorized by the Defense Technology Security Administration monitor. Contemporaneous Hughes records partially support this assertion. The monitor says he doubts that he in fact approved the disclosure, but says he cannot fully recall these matters.

Neither Hughes nor any relevant U.S. Government agency has been able to produce records substantiating all of the claimed approvals. Even if such approvals were in fact given, they would have exceeded the authority of the Defense Technology Security Administration monitor since he was not empowered to expand the scope of the license granted by the State Department. The monitor also should have known that a separate license was needed for the launch failure analysis activities. By the time of the 1995 failure investigation, partial jurisdiction for commercial

satellites had been transferred to the Commerce Department, but licensing for improvements to any part of the rocket, such as the fairing, remained with the State Department.

Hughes officials who were responsible for the launch failure investigation in 1995 knew that technical information that would improve the rocket, including the fairing, was still subject to State Department jurisdiction and was not licensed for export. Nonetheless, Hughes sought Commerce Department approval to disclose information regarding the fairing to the PRC. A Commerce Department official, without consulting with Defense Department or State Department experts, approved that disclosure, he says, on the assumption that the fairing was part of the satellite, not the rocket. He now acknowledges that this decision was a mistake.

The Defense Department recently determined that the information Hughes made available to the PRC was sufficiently specific to inform the PRC of the kinds of rocket changes and operational changes that would make the Long March 2E, and perhaps other rockets, more reliable. In particular, Hughes assisted the PRC in correcting the deficiencies in its models of the stresses or loads (such as buffeting and wind shear) that the rocket and payload experience during flight.

There are differing views within the U.S. Government as to the extent to which the information that Hughes imparted to the PRC may assist the PRC in its ballistic missile development. There is agreement that any such improvement would pertain to reliability and not to range or accuracy. It is not clear, at present, whether the PRC will use a fairing that was improved as a result of Hughes' disclosures in a current or future ballistic missile program. Currently-deployed PRC ballistic missiles do not use fairings, and the PRC's future mobile land-based intercontinental ballistic missiles will probably not use a fairing. However, fairings are used by the PRC in launching military communications satellites and could be used for a submarine-launched ballistic missile.

In the opinion of the Select Committee's independent expert, Dr. Alexander Flax, fairing improvements could also be of benefit to multiple independently-targeted reentry vehicle (MIRV) development, should the PRC decide to move in that direction. (See the *Technical Afterword* at the end of this chapter for additional details on the possible uses of fairings in intercontinental ballistic missiles.)

Hughes also provided the PRC with practical insight into diagnostic and failure analysis techniques for identifying and isolating the cause of a launch failure. Whether or not the structural improvements to the fairing suggested by Hughes are of immediate use to the PRC's missile programs, that information expanded the PRC's repertoire of available technical solutions to future problems that it may encounter in its space and missile programs.

Finally, the Select Committee's independent expert has concluded that Hughes provided the PRC with the benefit of its engineering experience and know-how. As a result, PRC engineers better understand how to conduct a failure analysis and how to design and build more reliable fairings for rockets: "This will stand them in good stead in developing fairings (or shrouds) for ballistic missiles."

OPTUS B2, APSTAR 2 LAUNCH FAILURES

PRC GAINS SENSITIVE KNOWLEDGE FROM HUGHES INVESTIGATIONS

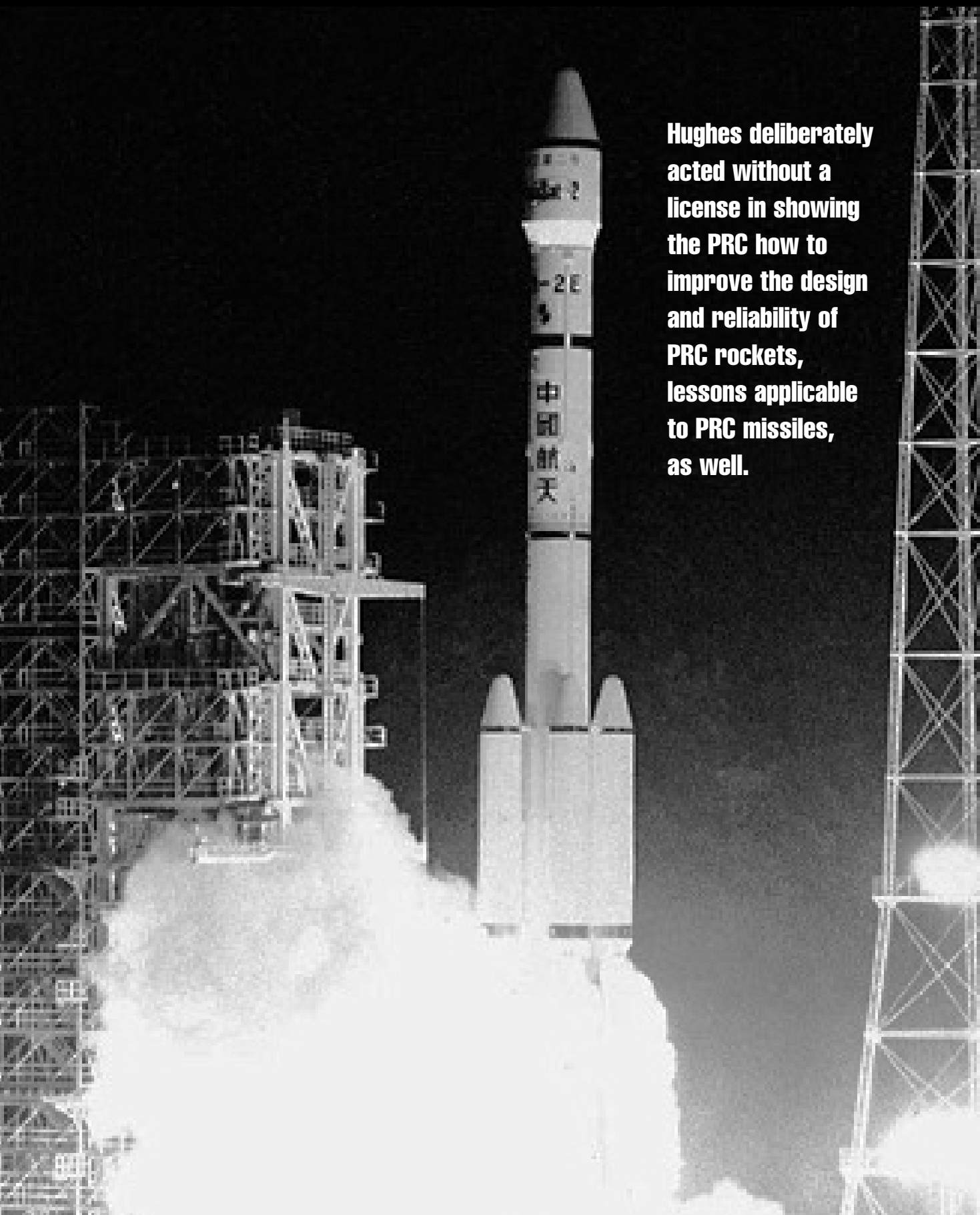
In 1992 and 1995, two Hughes Space and Communications International, Inc. (Hughes) satellites were launched from the People's Republic of China on Long March 2E rockets and failed to achieve orbit. It has been alleged that, in the failure investigations that followed, Hughes provided technical information to the PRC that assisted the PRC in improving the Long March 2E. This portion of the report examines the events that underlie those allegations.

The 1992 failure involved the Optus B2 satellite, while the Apstar 2 satellite was destroyed in 1995.

For each event, provided below is a brief discussion of the export licenses for the satellite, and the restrictions that the licenses contained.[1] A short discussion of the actual events of the failed launches follows, along with a detailed review of the failure investigations that Hughes conducted and of the U.S. Government's actions that related to those investigations.

Hughes' efforts during the investigations to provide technical information to the PRC for the purpose of assuring success in future launches are explained, as is the extent of the U.S. Government's knowledge and approval of Hughes' actions.

Finally, the actual improvements that were made to the Long March 2E by the PRC, and assessments of the potential damage to national security resulting from those improvements, are discussed.



Hughes deliberately acted without a license in showing the PRC how to improve the design and reliability of PRC rockets, lessons applicable to PRC missiles, as well.

The Prohibition Against Technology Transfer In Foreign Launches

International Traffic in Arms Regulations and the U.S. Munitions List

Section 38 of the Arms Export Control Act[2] (AECA) authorizes the President to control the export and import of defense articles and services. The International Traffic in Arms Regulations (April 1, 1992 edition) contain the following definitions of defense articles and defense services:[3]

> **Section 120.7 Defense article.**
>
> *Defense article means any item designated in Section 121.1. This term includes models, mockups, and other such items which reveal technical data directly relating to items designated in section 121.1*

> **Section 120.9 Defense service.**
>
> *Defense service means:*
> *(a) The furnishing of assistance (including training) to foreign persons whether in the United States or abroad in the design, engineering, development, production, processing, manufacture, use, operation, overhaul, repair, maintenance, modification or reconstruction of defense articles, whether in the United States or abroad….*

The U.S. Munitions List also enumerates articles that are controlled under the authority of the AECA in relevant part as follows:

> **Section 121.1 General. The United States Munitions List**
>
> *(a) The following articles, services and related technical data are designated as defense articles and services….*

> *Category IV – Launch Vehicles [rockets]….*
>
> *(b) Launch vehicles and missile and anti-missile systems including but not limited to guided, tactical and strategic missiles, launchers, and systems….*
>
> *(h) All specifically designed or modified components, parts, accessories, attachments and associated equipment for the articles in this category….*

Department of Defense Monitoring Role

U.S. Air Force Instruction 10-1210, "Technology Safeguard Monitoring for Foreign Launches of US Commercial Satellites," identifies the Defense Technology Security Administration[4] as having responsibility for the objectives of the technology safeguard program, which include:

> *to support the US non-proliferation policy for space and missile technology, . . . the International Traffic in Arms Regulations, and the US Munitions List.*[5]

Defense Technology Security Administration monitors are responsible for "controlling the disclosure of technical information."[6]

The U.S. Air Force Technology Safeguard Monitor Handbook describes the role of the Defense Technology Security Administration monitor in debris recovery and accident investigations as follows: "If an anomaly (i.e., crash) occurs during the launch campaign you will need to prevent technology transfer throughout the debris recovery and accident investigation." [7] It continues:

> *after an anomaly occurs, the chance for technology transfer is the highest. As a US government technology safeguard monitor you will be overseeing the accident investigation discussions. Failure analysis discussions are sensitive because both sides want explanations and ask technical questions. The worst case for possible technology transfer occurs when both the spacecraft [satellite] and*

launch vehicle [rocket] are suspect; however, technology transfer is still a problem even if the anomaly was clearly caused by a launch vehicle [rocket] problem.

Optus B2

The Optus B2 Licenses

On May 2, 1991, the U.S. Department of State issued export license 483414, renewing license 384476, dated March 16, 1989. The 1991 license permitted the export of two Hughes Model HS-601 satellites (see illustration) to Australia for delivery in space to Aussat (later renamed Optus), Australia's national communications satellite company.

The foreign intermediate consignee was Hughes, in care of China Great Wall Industry Corporation, Xichang Satellite Launch Center, Xichang, PRC.

The license was qualified by a letter dated May 2, 1991 from the Office of Defense Trade Controls of the State Department that sets forth limitations and provisos. In relevant part:

1. Hughes (which term includes all Hughes employees and agents) must conform strictly to the terms of Hughes own technology control plan with the China Great Wall Industry Corporation, as well as to the terms of the Satellite Technology Safeguards Agreement between the U.S. Government and the People's Republic of China (the Agreement) and the U.S. Government's measures for the implementation of that agreement.

* * *

5. Unless it obtains the prior separate approval of the Office of Defense Trade Controls of the U.S. Department of State, Hughes must not provide any hardware or technical assistance

Dept. of Defense

Built as the Hughes HS-601, this satellite became the Optus B2. It was to be placed in orbit from Xichang in the PRC for use by Australia's national communications satellite company. The December 21, 1992 launch failed, however, when the Long March 2E rocket veered off course and crashed, destroying the satellite. Hughes then tried to help the PRC fix the problems with the Long March.

> *whatsoever to its Chinese counterparts which might assist China to design, develop, or enhance the performance of any of its contemplated or existing Long March launch vehicles or missiles.*

The Optus B2 Fails To Achieve Orbit

On December 21, 1992, the Hughes-manufactured Optus B2 satellite was launched from Xichang Launch Center in the PRC.

The following description of the failure is excerpted from the Hughes report:

> *A normal performing launch vehicle [rocket] would have passed through the point of maximum dynamic pressure at 62 seconds after liftoff. The failure occurred approximately 48 seconds after liftoff. The launch vehicle [Long Mrach 2E rocket] was in the transonic buffeting period of its flight, at an altitude of approximately 7000 meters, when the failure occurred . . .*[8]

Debris recovery began almost immediately and continued for about three weeks.

Officials from the China Academy of Launch Vehicle Technology (CALT) and Hughes began to investigate the cause of the crash. Hughes President and CEO Steven Dorfman appointed Vice President Donald Cromer to lead the Hughes investigation to determine the cause of the failure.[9]

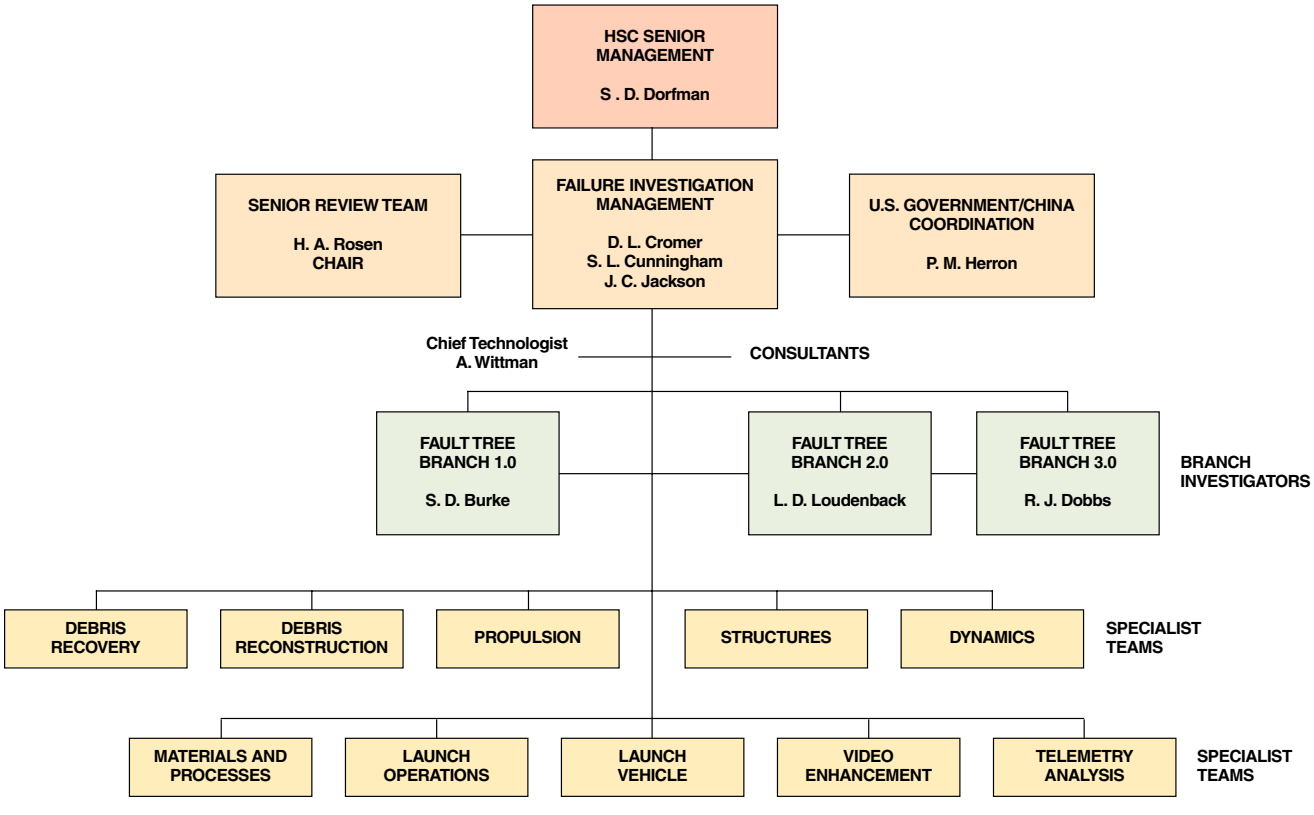
Before joining Hughes, Cromer, had been an Air Force Lieutenant General, and had managed the Space Division of Air Force Systems Command. In that position, he was responsible for the design, development, and acquisition of Air Force space launch, command and control, and satellite systems.[10]

Cromer's principal assistant in directing the Optus B2 failure investigation was Dr. Stephen L. Cunningham, a senior-level Hughes executive and Ph.D. physicist who has worked in satellite programs at Hughes since 1977.[11]

Hughes' Optus B2 Failure Investigation Organizational Structure

SENIOR TECHNICAL REVIEW TEAM

Team Role	Team Member	Position
Chair	Harold Rosen	Vice President, Engineering
Member	Jerry Dutcher	Business Unit Leader, GSEO
	Pete Herron	Optus B3 Program Manager
	John Ellison	Propulsion Product Line Leader
	Bob Meese	Business Unit Leader, SIS
	Steve Robinson	Chief Technologist
	Al Wittman	Chief Technologist
	Ted Smith	Consultant, Launch Vehicle
Advisor	Ernie LaPorte	Consultant, General
	Bob Steinhauer	Long March 2E Launch Vehicle
	Mal Meredith	Consultant, General
	Hal McDonnell	Galaxy Program Representative
	Steve Archer	UHF Program Manager
	Bob Roney	Consultant (retired Hughes VP)



Failure Investigation Teams

Hughes established several teams to conduct the Optus B2 launch failure investigation. The teams comprised 27 individuals, and their activities covered over 20 days of meetings with the PRC, including at least 15 days of meetings in the PRC.

A Failure Investigation Team was chartered to examine all aspects of the failure, including both the satellite and the rocket.

A second team, called the Spacecraft Focus Team, was to limit its focus to the satellite.

A third team, the Independent Review Team, was made up of experts from outside the Hughes organization. It was charged with reviewing the work of the other two Hughes teams and with making an independent assessment of the failure.

Finally, because Hughes recognized that the findings of its teams could be in conflict with those of the PRC accident investigators representing the China Academy of Launch Vehicle Technology (CALT), it established the International Oversight Team made up of three members: one from Intelsat, one from the China Aerospace Corporation (CASC), and the Chairman of the Hughes Independent Review Team.

The Hughes teams were organized by functional specialties as illustrated in the chart on the previous page.[12]

The organization chart identifies Peter M. Herron, who was the Optus B2 Assistant Program Manager, as responsible for U.S. Government/PRC coordination for the failure investigation. In this role, Herron was the person responsible for obtaining U.S. Government approval for all information transfers from Hughes to the PRC during the failure investigation.[13]

Failure Investigation Begins

The failure investigation began immediately, and proceeded as shown on the following page.[14]

As the debris recovery progressed, Defense Technology Security Administration monitors who were present for the launch continued to monitor the recovery efforts.[15]

Hughes' Optus B2/Long March 2E Failure Investigation Schedule

EVENT	1992 DEC	1993 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
Launch Failure	▲ 21										
Failure Team Reviews	▲▲	▲▲▲▲	▲	▲▲▲▲▲	▲						
Debris Recovery	▲—▲										
Team Visit China		▲ 7-12									
Debris Received		▲ 21									
Launch Vehicle Telemetry 1 Received		▲ 29									
Interim Spacecraft Report			▲ 19								
Telemetry Team Visit China				▲ 1							
UHF F1 Launch (Atlas)				▲ 11							
Preliminary Spacecraft Report					▲ 30						
China Closeout Meeting						▲ 11					
Astra 1C Launch (Ariane)						▲ 12					
Launch Vehicle Telemetry 2 Received						▲ 15					
Galaxy C2 Launch (Ariane)							▲ 24				
Optus Briefing — HSC								▲ 12			
Optus Briefing — CALT								▲ 15			
UHF F2 Launch (Atlas)										▲ 3	
Underwriters Briefing											▲ 30
Final Spacecraft Report						▲ Coordination Draft					▲

The Hughes Optus B2 launch failure investigation spanned nearly a full year during 1992-93.

Defense Technology Security Administration monitors were also present during the subsequent failure investigation, both in Beijing and Xichang, whenever Hughes employees had meetings with PRC officials.

U.S. Air Force Lieutenant Colonel Allen Coates was one of the Defense Technology Security Administration monitors. He was present in Beijing from January 4 to 14, 1993 as a Defense Technology Security Administration monitor for the failure investigation.

Lt. Col. Coates specifically recalls informing Hughes senior management, including Vice President Donald Cromer, Chief Technologist Al Wittmann, Chief Scientist Robert Steinhauer, and Optus B2 Assistant Program Manager Peter Herron of the restrictions in Hughes' export license regarding the transfer of any information related to the design of the satellite or the rocket.[16] He additionally advised Hughes personnel there, specifically Herron, and possibly Steinhauer and Wittmann, that Hughes could not discuss modifications to the fairing.[17] At that time, Al Wittmann, Chief Technologist at Hughes, reported directly to CEO Steven Dorfman.[18]

In the early stages of the investigation, the PRC focused its analytic efforts on the rocket, and Hughes examined the satellite. Both the PRC and Hughes were seeking to determine whether their respective hardware was responsible for the failure. Because the first visible sign of an explosion appeared as a flame at the top of the rocket, there was some question as to whether the satellite could have exploded.

As part of the investigation, Wittmann, Hughes' Chief Technologist, and the other engineers first looked into the possibility that the satellite fuel tank structures failed. They later determined the fuel tanks did not fail.[19]

Upon his return from the PRC, Wittmann had an accident that forced him to recuperate at home. During his recuperation, he was assisted by Spencer Ku, another Hughes engineer. In reviewing some of Ku's analysis, it occurred to Wittmann that statements made to him by PRC personnel regarding the structure and materials strength of the rocket's fairing (that is, the portion of the rocket including the nose cone that surrounds the satellite) were not realistic.[20]

Wittmann was sure in January 1993, while still in recuperation, that the fairing[21] that surrounds the satellite failed, thus collapsing and crushing the satellite.[22]

As the investigation progressed, Hughes scientists became more and more certain that the fairing on the Long March 2E rocket had indeed failed, causing the launch failure.

Hughes' Export Administrators Deal with the Licensing Question

Hughes' Technology Export Control Coordinator, Donald Leedle, was the focal point in the company from 1992 until 1996 for technology licensing issues. A program or contracts manager who needed to export a satellite would consult him for information regarding licensing requirements. He was responsible for maintaining current knowledge of governmental regulations related to export licensing.[23]

Leedle describes himself as one of the most knowledgeable Hughes employees on the subject of the International Traffic in Arms Regulations as they relate to communications satellites. He says he was responsible for briefing Hughes program managers on these regulations. He was also responsible for coordinating licensing conditions and requirements for the Hughes programs. He consulted with Hughes Electronics' corporate International Traffic in Arms Regulations expert, Dar Weston, when necessary.[24]

Leedle says that the Optus B2 licenses, as many as 18, had been approved before he was involved in the Optus program. Some licenses had expired, however, and he was involved in the renewal by the State Department of the expired licenses.[25]

In response to a general question about the need for a license for a failure investigation, Leedle says that an accident investigation might be covered by the original license, or it might need a new license, but such a decision would be made by the U.S. Government. He advises that technical data would require different State Department licenses than the satellite hardware. Further, he says that Hughes was not permitted under the International Traffic in Arms Regulations to make suggestions that would help improve PRC rockets.[26]

Leedle is aware that rockets are included on the Munitions List and that a fairing is a part of the rocket.[27]

Sometime after the Optus failure, Leedle met with a group of Hughes employees, among them Hughes attorney Jennifer Smolker[28] and Peter Herron, who had been the Assistant Program Manager for the Optus B2 satellite, to determine whether a license was needed for the failure investigation.[29] Hughes CEO Dorfman describes Smolker as "the first point of accountability, from my perspective, on the whole licensing process." [30]

In April 1993, Leedle most likely contacted Donald E. Majors, Director for International Affairs at Hughes' Washington, D.C. office, regarding Hughes communications with the PRC concerning Long March 2E rocket fairing deficiencies. Although he does not specifically recall the conversation, he says that he talked frequently to Majors during that period.[31]

On April 9, 1993, Majors wrote a memorandum to Leedle on "License Requirements for Long March Fairing Discussions," in which he summarized informal discussions with the State Department regarding the Optus B2 launch failure investigation.[32] The text read:

> ***1.*** *In response to our informal inquiry, the cognizant State Department licensing official expressed the following views:*
>
> ***a. Information or professional opinion on fairing deficiencies as a potential cause of the Optus B2 launch failure probably constitutes technical data as defined in ITAR [International Traffic in Arms Regulations]. If Hughes decides this is in fact the case, an export license would be required to provide such information or opinion to the PRC.*** *If Hughes decides otherwise, the subject is moot.*
>
> ***b.*** *If a license is required, chances of obtaining it would be good if Hughes could make an unequivocal case that the technical data to be transferred could not be used for any purpose other than increasing the safety of the spacecraft during a new launch.*
>
> ***c. A license request would almost certainly be denied if even the slightest possibility or inference, real or perceived,***

> ***remained undispelled that the technical data could directly or indirectly impact PRC ballistic missile interests.***
>
> ***2.*** *Should [Hughes] elect to submit a license application on this subject we recommend that (a) all the technical data to be transferred be precisely stated and (b) detailed rationale be included to counter all potential arguments that the data could in some way enhance PRC ballistic missile capabilities.*
>
> ***3. Considering the extreme sensitivity that certain USG agencies attach to technology transfers to the PRC, we should also give some thought to an advance softening up process.*** *This could include advance technical level briefings for friends and adversaries alike, and a degree of precoordination of the data to be released.* [Emphasis added]

Majors' memorandum to Leedle was also sent to Herron and Smolker. Additionally, copies of the memorandum were forwarded to the following Hughes executives: CEO Steven Dorfman, P. C. Dougherty, M. J. Houterman, W. D. Merritt and J. S. Perkins.

Majors' office served as the Washington liaison between Hughes corporate offices and the State Department on licensing issues. His primary contact on satellite issues at the State Department licensing office was Kenneth Peoples.[33]

Peoples had issued State Department export license number 483414 to Hughes for the export of the Aussat B (later Optus B) satellite. He says that the license defined authorized activities, and that any activity not specifically authorized by a license is prohibited.[34]

Peoples advises that rockets are on the Munitions List and that a fairing, the nosecone that protects the satellite, is a part of a rocket.[35] Peoples does not specifically recall speaking to Majors about the fairing, but he describes the recommendation in Majors' memorandum as "excellent advice." The fact that rocket information was on the Munitions List in 1993 was well-known, he says, and Peoples has difficulty accepting that Hughes officials would not have been aware at that time that a license would be needed to convey to the PRC information related to rockets.[36]

Mere unlicensed discussion of technical data with foreign nationals is sufficient to constitute a violation of the International Traffic in Arms Regulations, in Peoples' opinion. In addition to the license restrictions, Hughes was prohibited from transferring technology to the PRC by provisions of the U.S./PRC nation-to-nation agreement on technology transfer.[37]

Stephen Cunningham, who led the Optus B2 launch failure investigation, had also been the Program Manager for the Optus B1, which was launched in the PRC in August 1992. He is familiar with the International Traffic in Arms Regulations and the Munitions List. Cunningham agrees that Hughes needed prior, separate approval from the State Department to provide any technical assistance that might assist the PRC in enhancing the performance of its Long March rockets.[38]

Around the time of Majors' April 9, 1993 memorandum, Cunningham recalls "specific discussions with [Defense Technology Security Administration monitor Lt. Col.] Al Coates regarding whether the fairing we are talking about had any relevance to ballistic missiles, and we did not receive a specific answer from Al Coates, but he said he would go find out from his sources." [39]

Cunningham says that Hughes hypothesized that the fairing on a commercial satellite had no relevance to ballistic missiles:

> *We were all very sensitive to the issue on anything that would help the ballistic missile interest, but — and there are a lot of things in the commercial satellite business that are irrelevant to weapons use and so the real question was, in our minds, is the fairing that we are talking about in the category of commercial use only or is it in the category of missile technology?* [40]

On April 19, 1993, ten days after the MajorsΔ memorandum, a senior level staff meeting took place at Hughes to discuss how to deal with the fairing issue. Officials at the highest levels of Hughes, including possibly Vice President Cromer, attended the meeting, which was held to discuss a planned trip to the PRC regarding both the Optus B2 failure and the future launch by the PRC of Optus B3, the satellite that was to replace the destroyed Optus B2.[41]

Cunningham's participation in the trip to the PRC was in connection with his duties to discuss and resolve issues related to the Optus B2 failure. While on the same trip, his colleague Peter Herron was involved in negotiations regarding the Optus B3.[42]

By April 1993, Cunningham says, "We strongly believed that the fairing caused the problem . . . We believed that the fairing had to be modified in order to get insurance to launch." [43]

Herron had prepared view graph slides, outlining the issues and alternatives for senior management to consider at the strategy meeting. One of the slides used in the briefing stated the following:

> *We are concerned about several aspects of the design [of the Long March 2E fairing]. What do they fix? How do they validate the redesign?*
>
> *The USG will require a specific license if we want to discuss the design problems. It is unlikely that we could get the license.*
>
> *We would have to show that there would be no resultant improvement in the Chinese ICBMs.*[44]

A 'Political' Business Solution

Hughes' Director of Launch Service Acquisition, John S. Perkins, was responsible for the negotiation of the Optus B3 launch services contract with the PRC. In that role, he had contact with the team investigating the Optus B2 failure. Although he was not part of the Optus B2 failure investigation team, he was in the PRC conducting Optus B3 negotiations while the failure investigation was proceeding.[45]

Perkins recalls being aware during the failure investigation that some Hughes engineers thought that the fairing on the Long March 2E rocket may have failed. He recalls that there were discussions within the company that Hughes would require the PRC to improve the fairing, and that without improvements to the fairing, the Optus B3 would not be launched.[46] Perkins says that the negotiations for an agreement to announce the conclusion of the Optus B2 failure investigations took several weeks of "wordsmithing to subtly try to imply the other party was at fault, without being at fault, to point the finger at us or to point the finger at the Chinese." [47]

The negotiations for Optus B3 were difficult, because the PRC would not acknowledge any fault in the Optus B2 failure. It is Perkins' belief that the Defense Technology Security Administration eventually approved some discussions with the PRC about fairing improvements.[48]

Perkins also participated in discussions with the PRC that led to a written agreement that took the following form:

MINUTES OF MEETING HELD IN BEIJING
ON 11 TO 12 MAY 1993
BETWEEN HUGHES AND CGWIC
REGARDING THE CONCLUSION
OF THE OPTUS B2 FAILURE INVESTIGATIONS

1. *On December 21, 1992 the Optus B2 satellite was launched on an LM-2E Launch Vehicle from Xichang Satellite Launch Center, China. At approximately 48 seconds into the flight, the Optus B2 spacecraft exploded.*

2. *Based on analysis of the Launch Vehicle telemetry, inspection of the Launch Vehicle fairing debris and special tests, it was determined by CGWIC/CALT [China Great Wall Industry Corporation/ China Academy of Launch Vehicle Technology] that there is no design or manufacturing or integration flaw in the Launch Vehicle or the fairing which caused the failure. Hughes accepts this conclusion.*

3. *Based on analysis of the Launch Vehicle telemetry, inspection of the spacecraft debris, and special tests, it was determined by Hughes that no design or manufacturing flaw can be found in the spacecraft which caused the failure. CGWIC/CALT accepts this conclusion.*

4. *Both CGWIC/CALT and Hughes agreed to conclude the Optus B2 investigation and use their best effort to launch another Optus satellite by June 94.*

5. During the Optus B2 failure investigation, both CGWIC and Hughes observed strictly the requirements of the USA/PRC agreements on technical security.

6. Both parties expressed the same willingness to promote the existing friendly cooperation between them. Hughes expressed the willingness to purchase Long March launch services for other future satellite programs, and CGWIC expressed the willingness to influence its partners to purchase Hughes' satellites.

Signed on the 12th day of May 1993

Donald L. Cromer	***Wang Dechen***
John S. Perkins	***Chen Shouchun***

Perkins describes this agreement as an agreement not to publicly blame the fairing as the cause of the failure. Perkins says of the agreement:

> *Politically we could not write down on paper that the fairing had failed and that they were at fault. It was a non-starter in China. They were very concerned that we would say that. This document was trying to say we are not going to say that. Now, go fix the fairing.* [49]

Hughes' intermediary in the PRC was Bansang "Bill" W. Lee, who worked in the Hughes Beijing office from 1991 until around October 1994 as a salaried employee.[50] As Hughes' chief representative in Beijing, he had three duties: marketing Hughes satellites in the PRC; serving as a liaison between various Hughes organizations and the PRC; and providing logistics support for all Hughes visitors to the PRC.[51]

Although Bansang Lee was not actually a member of the Optus B2 failure investigation team, he was present at meetings in the PRC and was involved in the negotiations that led to the May 12 agreement between Hughes and China Great Wall Industry Corporation not to blame each other for the launch failure. He was also involved in negotiations for the Optus B3 launch.[52]

Lee's major involvement in the failure investigation was crafting an acceptable public explanation as to the cause of the failure. The PRC would not accept that the Long March 2E rocket was at fault, and Hughes was almost certain that the satellite had not caused the failure. Lee says that in the May 12, 1993 agreement each side stated: "I have no objection to your position . . . and you have no objection to my position. Basically, the conclusion is no conclusion." [53]

Lee says that his involvement in efforts between April and October 1993 was generally along the lines of persuading each side not to point fingers at the other. He says that he was not directly involved in attempts by Hughes to convince the PRC that the fairing was the problem, although he was aware that a number of people within Hughes believed that. He was also aware of at least one, Harold Rosen, who did not hold that belief.[54]

Lee further says that in the negotiations, during which Lee served as Hughes CEO Dorfman's liaison to PRC Minister Liu Jiyuan,[55] Minister Liu confirmed Hughes' understanding that once a suitable agreement had been signed, the PRC would be willing to consider making modifications to the Long March 2E rocket before the next launch.[56]

In addition, Lee says that Hughes "is not saying how to fix it, but wording [sic] requirement that they have to finally fix it." Lee says he was aware that a number of Hughes engineers, particularly Al Wittmann, believed that the fairing had indeed failed.[57]

In June 1993, Hughes Chief Technologist Al Wittmann wrote a paper analyzing how he thought the fairing had failed, and how the fairing could be improved to prevent a similar failure in the forthcoming Optus B3 launch. The paper sought permission within Hughes to communicate the results of his analysis to the PRC. Wittmann says he discussed the recommendations in his paper with Peter Herron, who was coordinating the launch failure investigation with the PRC; Hughes Vice President Donald Cromer; and Stephen Cunningham, who was heading up the launch failure investigation.[58]

Wittmann recommended that Hughes not launch the Optus B3 on the Long March 2E rocket unless the PRC made improvements to the fairing. He says that 70

to 80 percent of the Hughes team members agreed with him, and that Cromer, Cunningham, and Herron supported his view that the Optus B3 should not be launched without changes to the fairing.[59]

When Wittmann discussed his paper with Herron, Herron responded by telling Wittmann that, unless the fairing recommendations in the paper were simplified considerably, he was not willing to ask the U.S. Government for approval to share it with the PRC. Wittmann says Cunningham had also asked him to revise the paper for the same reason.[60]

Hughes CEO Dorfman also recalls discussions with Wittmann about the fairing:

Q: *Would you describe the changes that . . .Wittmann may have brought to your attention as changes which would improve the fairing?*

A: *Well, the only thing I can remember is that Mr. Wittmann . . . felt that the fairing . . . had an overlap problem, and that there would be a gap that could be caused during ascent between the two halves of the fairing, and that that gap might cause a pressure differential which would separate the fairing.*

Q: *Would that suggestion constitute, in your view, an improvement to the fairing?*

A: *I don't know.*

Q: *Is it a modification to the fairing?*

A: *If they made a change, it would have been a modification.*

Q: *So Mr. Wittmann recommended something which, if it had been accomplished, would have been a modification to the fairing?*

A: *Yes.*[61]

Additionally, Hughes Vice President Cromer recalls the following discussion with Wittmann about the fairing:

Q: *When Mr. Wittmann first approached you about his concerns regarding the fairing, do you recall some of the technical aspects that he mentioned . . . ?*

A: *Yes.*

Q: *Can you tell us what some of those were?*

A: *He was concerned about two aspects particularly. One is the strength of the rivets that held the fairing together and this was an issue of having adequate strength to withstand the launch loads but still having sufficient ability to open the fairing when you needed to. So it's a balance of strength versus separating the fairing under the right conditions. Also the nose cap and its design and how it might be affected by the loads during the ascent.* [62]

Hughes launch failure investigators Herron and Cunningham subsequently prepared a group of viewgraph slides that simplified the contents of Wittmann's paper. Herron, who was responsible for coordinating with the PRC, then submitted these to Defense Technology Security Administration monitor Al Coates for approval. Coates' signature approving the transfer of this information to the PRC appears on a facsimile transmittal sheet, dated June 25, 1993.

Lt. Col. Coates says he does not recall approving this transfer, and he doubts that he would have ever approved the disclosure of such prohibited information. He further says he did not have the authority to approve the disclosure of information that could have improved the PRC rocket. He also says that it was always clear to Hughes that no data that could improve the rocket could be transferred to the PRC.[63]

Generally, Coates recalls that the Defense Technology Security Administration always emphasized in briefings for Hughes employees the prohibition against improving the rocket. He says that Hughes personnel were very knowledgeable about the export control process, and that Herron undoubtedly knew of the restrictions regarding rocket improvements.[64]

Coates specifically recalls telling Herron that he could not discuss the design of the fairing with the PRC.[65]

Coates says he maintained a program file at the Defense Technology Security Administration that contained all his approvals related to the Optus B2.[66] Such a file could not be found among the materials provided to the Committee by the Defense Technology Security Administration.

Hughes failed to respond to the Committee's interrogatories (which included a request for documents) regarding these approvals.

Donald Leedle, who was responsible for Hughes' technology export control, says Herron contacted him to inform him that Coates had approved communicating the information on improving the fairing to the PRC. In Leedle's deposition, the following exchange regarding improvements to the Long March 2E rocket occurred:

Q: *Does this document suggest specific changes to the Long March 2E fairing for the Hughes satellite that would improve the fairing?*

A: *At the bottom of the page it says. 'Add a bracket or block to prevent any possibility of overlap of the two fairing halves.'*

Q: *What about on page 2?*

A: *'Increase the strength of the rivets along the separation line.'*

Q: *So, in your view, does this document propose specific technical improvements to the fairing?*

A: *I think they are fairly generic. Add a bracket and strengthen a rivet is not very specific.*

Q: *Are those improvements to the fairing?*

A: *They may be.*

Q: *Is Mr. Herron suggesting in his letter that they are?*

A: *He certainly feels that if these things are accomplished, that there is less likelihood of it failing.*

Q: *So would you view this letter as Mr. Herron's statement that these changes would improve the fairing?*

A: *Well, I'm not sure – 'improve' is a difficult word. It would prevent failure – It might prevent a failure.*

Q: *Mr. Wittmann suggested improvements to the fairing in his letter, correct?*

A: *Uh-huh.*

Q: *Mr. Herron in a letter to Mr. Lee is now suggesting changes need to be made to the fairing. Those changes presumably would improve the fairing, would they not?*

A: *I don't know the answer to that.*

Q: *I'm asking you to look at Mr. Herron's letter – you had discussions with Mr. Herron – and tell me whether you think he is suggesting things that would improve the fairing?*

A: *He is making recommendations to prevent a failure.*

Q: *By 'prevent a failure,' would you say that improving the fairing would help prevent a failure?*

A: *Something would have to be done to the fairing to prevent a failure.*

Q: *Improving the fairing is what this letter is about; is that correct?*

A: *Uh-huh.*

Q: *And you've already told us that the fairing is a part of the launch vehicle; is that correct?*

A: *That's correct.*

Q: *So the improvements to this fairing, it logically follows, would result in improvements to the launch vehicle. Do you agree?*

A: *If they were actually improvements.*[67]

In Cunningham's deposition, the following exchange about improvements to the fairing took place:

Q: *So, in your view, that doesn't constitute an improvement in the fairing?*

A: *If they do these correctly, and they have to define correctly, this would improve the fairing. But if they do – but without further analysis, this would not improve the fairing. This in itself does not improve the fairing.*

Q: *Is it a modification of the fairing?*

A: *Yes.*

Q: *I want to go back just briefly to Exhibit 1, paragraph 120.9, defense service; it's on the second page of Exhibit 1.*

> *'120.9 (a), Defense service means: the furnishing of assistance to foreign persons,' skip a little bit,'whether in the United States or abroad in the design, development, engineering, manufacture, production, assembly, testing, repair, maintenance, modification, operations, demilitarization, destruction, processing or use of defense articles.'*

Is — would these suggested improvements constitute a modification of the fairing?

A: *Yes, they would.*

Q: *To modify a fairing or to modify a defense article, do you need a license — according to what you read in ITAR [International Traffic in Arms Regulations] earlier?*

A: *Yes, we do.*

Q: *And did you obtain a license to provide this information to the Chinese?*

A: *No.*[68]

Leedle says he was surprised that Herron, Hughes' Assistant Program Manager for the Optus B2 and the person responsible for coordinating the failure investigation with both the U.S. Government and the PRC, bypassed him and approached the Defense Department's Coates directly. Leedle acknowledges that the purpose of Wittmann's fairing recommendations was to prevent the rocket from failing in future launches. Leedle and Cunningham acknowledge that improvements to the rocket required a State Department license, and that, to the best of their knowledge, no such license was ever applied for.[69]

On July 15, 1993, Hughes CEO Dorfman wrote expressing his concerns about the cause of the Optus B2 launch failure to PRC Minister Liu Jiyuan, President of China Aerospace Corporation, in care of Hughes' Bansang Lee, stating in part:

> *After listening to Wang Dechen's [the PRC designer of the Long March 2E rocket] presentation last week, I've become very concerned that we will not convince our customer and insurers that it is safe to launch Optus B3.*
>
> *I emphasize that you must 1) demonstrate a thorough and objective evaluation of potential causes for the accident, and 2)* ***make appropriate design and process changes to prevent recurrence,*** *even if a definitive cause cannot be identified.*
>
> ***Our people have made some specific suggestions which I urge you to consider.***[70] [Emphasis added]

On July 18, 1993, Bansang Lee reported to Dorfman the results of the meeting with Minister Liu at which he delivered Dorfman's letter. Lee wrote about the PRC's

strong negative reaction to Hughes' statements that appeared to blame the PRC rocket for the Optus B2 failure, in violation of the May 12 agreement:

> *Mr. John Perkins letter of July 9, 1993 clearly pointed out the [Long March 2E rocket's] fairing was the cause of the launch failure . . .*
>
> *It is true that it looks like the whole world appears to believe the trouble was caused by the rocket . . . CGWIC [China Great Wall Industry Corporation] has reasons to believe that Hughes is making a trap to get them . . . If they agree to make any change to the fairing now, they are walking into the trap themselves.*[71]

As Bansang Lee continued to negotiate, he says he thought that Hughes Chief Scientist Robert Steinhauer, who had worked closely with the PRC for almost ten years, might be able to help allay the PRC's concerns.

On August 5, 1993, Bansang Lee wrote to Hughes CEO Dorfman suggesting that Steinhauer bring the Optus B2 failure report to the PRC and meet with the chief designer of the Long March 2E rocket, Wang Dechen, to go over the findings.[72]

On August 15, 1993, Hughes and China Great Wall Industry Corporation issued a joint news release, reported in *Space News,* stating that although no design flaws were found, both companies would make improvements to their products. *Space News* quotes an insurance broker as saying that, "evidence points to a structural flaw in the rocket's fairing which probably imploded during launch." It also quotes a U.S. satellite underwriter as saying the companies

> *had narrowed the cause of the launch failure to a few possibilities, but struck a compromise on the announcement because they are still doing business together.*
>
> *Hughes also wants to support the Long March because the company is concerned about becoming overdependent on the Arianespace launch consortium of Evry, France.*[73]

On August 23, 1993, Steinhauer went to the PRC and met with the designer of the Long March 2E rocket, Wang Dechen. Since 1985, Steinhauer had been Hughes' primary contact with the PRC on the use of their rockets. He also served as a consultant to the Optus B2 failure investigation team from January 1993 through October 1993, attending many of the failure investigation team meetings, and also meeting with the PRC regarding the failure investigation.

The purpose of Steinhauer's August meeting in the PRC was to try to help resolve things between the two companies. In particular, Steinhauer focused on Wang Dechen, the designer of the Long March 2E. Hughes believed that Wang Dechen was the key PRC individual who had to be turned around.

On September 14, 1993, Hughes Chief Scientist Steinhauer wrote a memorandum to Hughes Vice President Cromer suggesting a hard negotiating position with the PRC on the issue of the fairing failure. The memorandum said: ". . . Hughes should make an unequivocal statement to Minister Liu Jiyuan that Optus B3, or any other Hughes spacecraft, will not fly on the LM-2E without modifications to their launch vehicle fairing."

The memorandum also describes Wang Dechen as "digging in his heels" against the idea of a unified presentation identifying the failure cause for the insurance community. Cunningham advises that earlier in the investigation Wang Dechen had publicly stated that the rocket was not the cause of the failure.[74]

Hughes Vice President Donald Cromer says that it was his decision whether Hughes would launch Optus B3 on a Long March 2E rocket. His decision was that Hughes would not launch unless the China Academy of Launch Vehicle Technology made improvements to the fairing.[75]

In a September 9, 1993 message to Cromer, Bansang Lee made a number of recommendations related to future business relations between Hughes and the PRC in preparation for the Optus B3 insurance underwriters' briefing that was scheduled later in September. Bansang Lee wrote:

> *In reality by insisting that the rocket has a problem at the fairing will do [sic] harm to Hughes in the following major areas:*

It will be even more difficult for the rocket to obtain insurance. This will make the Optus B3 program more expensive and more difficult to resolve.

Furthermore, it will make the APT II [the PRC-controlled Asia Pacific Telecommunications Satellite Co.'s next Hughes satellite] more difficult to obtain insurance as well. This will hurt Hughes a lot more than CGWIC [China Great Wall Industry Corporation].

We will have a 'war' to fight, not only with CGWIC, but with China in general. This will not only hurt our satellite business in China but will generally be harmful to all Hughes activities in China for years to come.

What do we get out from [sic] this? I could not think of any [sic] that is good and useful to Hughes. The only small thing that I could think of is that in the future we could claim better reliability statistics on our satellites.

If we swallow this one and let our Chinese friends off the hook, it will actually do more good for Hughes . . .[76]

On September 10, 1993, Hughes Vice President Cromer asked Bansang Lee to bring Cromer's concerns to the attention of the highest levels of the PRC:

However, of even greater disappointment is the continued insistence by Wang Dechen [the PRC's Long March 2E rocket designer] that we change the conclusion of our failure investigation. He has signed an agreement that he accepts the results of our investigation yet he continues to demand we modify the results to suit his view of the accident . . .

We (Hughes and CALT) must make a full disclosure of all relevant facts and data surrounding the accident to the insurance community . . .

> *It is mandatory that we both make whatever changes are necessary to add margin to our designs. We are doing so on the satellite side and are prepared to disclose these at the insurance briefing. The Chinese must be able to state that they will do likewise . . .*
>
> *They cannot be superficial improvements — they must be substantial and directly related to a possible failure cause.*[77]

On September 15, 1993, the Hughes official coordinating the launch failure investigation with the PRC, Peter Herron, wrote to Bansang Lee about the insurance briefings. Herron asked Lee to inform the PRC that Hughes was willing to remove all information from the insurance briefing related to the Long March 2E rocket from its presentation at the insurance briefing. But Hughes would do this only if the China Academy of Launch Vehicle Technology presented the data that Hughes was deleting. In his letter, Herron wrote:

> *While we would not plan to talk about the fairing debris, it is important for full disclosure that CALT [China Academy of Launch Vehicle Technology] also address the following:*
>
> *Debris — The CALT report makes blanket statements that there were no delaminations. However, it is obvious that there were a number of small delaminations, both on the inside of the cylindrical portion of the fairing and along one edge of the nose cap. They [CALT] must explain why they think these occurred and what the relationship to the event [crash of the Long March 2E] is, if any . . .*[78]

By late September, Hughes and the PRC had decided, pursuant to their May 1993 agreement, that Hughes would not brief the issue of the fairing to the insurers.

The PRC had earlier signaled to Hughes' Bansang Lee that it would consider making modifications to the fairing for the Optus B3 launch.[79] Hughes Vice President Cromer confirms that Hughes made a decision to go forward with

Optus B3 because the China Academy of Launch Vehicle Technology had committed itself to modifications to the Long March 2E rocket's fairing.[80]

On September 30, 1993, Hughes and PRC representatives met with the Optus B3 space insurance underwriters in London to discuss the conclusions and results of the Optus B2 failure investigation. Cunningham, as the head of the Hughes failure investigation, led the company's presentation.[81]

At the time of the insurance briefing, the Hughes final investigation report was not yet finished. Although Cunningham was the author of the Hughes Optus B2 Failure Report, he says he did not distribute the report to anyone outside of Hughes, and he does not know whether anyone else at Hughes did so.[82]

Cunningham says that the Hughes failure investigation report was sufficiently technical that Defense Technology Security Administration approval would have been necessary for it to be exported. He does not know whether the report was ever given to the PRC, but he doubts it was.[83]

Cunningham says that the U.S. insurance underwriters may have been separately briefed by Hughes about its concern that the Long March 2E fairing was defective and needed modifications. Hughes claims that the Defense Technology Security Administration was not present at the insurance briefing because it chose not to attend. Defense Department monitor Coates claims he was told by Hughes that no PRC representatives would be present at the briefing.[84]

Hughes Vice President Cromer testified that C. Michael Armstrong, at that time Chairman and Chief Executive Officer of Hughes Electronics Corporation, was generally aware of the analysis of the 1992 failure. Cromer updated Armstrong on the progress of the investigation.[85]

Armstrong, however, testified that although he was aware of the Optus B2 failure, he could not recall any information about a failure investigation.[86]

The Optus B3: Hughes' Efforts to Improve the Long March Continue

Between October 1993 and August 1994, when the Optus B3 was successfully launched, Hughes continued its efforts to have the PRC improve the Long March 2E fairing.

On October 13, 1993, Peter Herron, in his role as Program Manager for Optus B3, wrote to Bansang Lee regarding changes to the Long March 2E. Herron wrote, in part:

> *4. We need to discuss the possible changes to the LM-2E [Long March 2E]. How do we get the changes made?*
>
> *I suspect it is unlikely that CALT [China Academy of Launch Vehicle Technology] will recommend changes to the fairing, since that might be seen by them as an admission that something was wrong. (Why else make a change?)*
>
> *They have stated that they would make changes that their customers require. This was stated in the press release, was stated by Wang Liheng at the dinner with Don Cromer in September, and was stated by Wang Dechen during the meeting with the underwriters in London. However, we are not LV [rocket] experts and are not in a position to make recommendations for improvements.*
>
> ***Further, the USG would not be likely to allow us to make recommendations in the current environment.***
>
> *This is my idea. Last summer we requested that CALT respond to our concern with the nose cap (you will recall the four viewgraphs we prepared and showed to Wang Dechen [the PRC's Long March 2E designer] as well as the bad reaction that resulted).*
>
> *I think we can use these same viewgraphs to request that CALT examine some 'Hughes requested' changes to the fairing.*

Specifically, we can ask for CALT ideas on how they would implement changes that would,

1. Add a bracket or block to prevent any possibility of overlap of the two fairing halves,

2. Increase the strength of the rivets along the separation line. . . [Emphasis added]

The Defense Department's Lt. Col. Coates says that, had he been asked, he would not have approved the transmittal of this information to the PRC. He also says that Hughes personnel knew that each separate transmission of information to the PRC required specific approval.[87]

On October 20, 1993, Peter Herron, Hughes' program manager for the Optus B3, wrote to Chen Shouchun, Vice President of the China Great Wall Industry Corporation, regarding Optus B3 meetings scheduled for November 1993 at Hughes. One topic of Herron's letter is ". . . discussions of ways to improve margins for the next launch. CALT [the China Academy of Launch Vehicle Technology] has already committed to make some changes to the LM-2E [Long March 2E rocket] in accordance with our needs."

Hughes and the PRC held design meetings in November 1993, to discuss the proposed modifications to the fairing.

The Optus B3 was licensed by the Commerce Department, not the State Department. Other than the license for the Optus B3, which was approved by the Commerce Department, Herron did not submit any Optus B3 fairing improvement documents to the U.S. Government for approval.

Steven Burke, a structural analysis engineer at Hughes and principal investigator on the Optus B2 investigation, recalls attending a number of Optus B3 design review meetings with the PRC. During the early portion of the Optus B2 failure investigation, Burke had been responsible for analyzing Optus B2 rocket telemetry data supplied by the PRC. Burke and fellow engineer Spencer Ku had determined, along with Hughes' Chief Technologist Al Wittmann, that the fairing had caused the failure.[88]

On May 9, 1994, Burke wrote a detailed technical paper entitled "Optus B3/LM-2E Fairing Design Review," discussing a meeting with the PRC that occurred on May 2, 1994 regarding fairing improvements to the Long March 2E needed for the upcoming Optus B3 launch. He says the meetings were both political and technical in nature: political in that the PRC was unwilling to admit fault, while from a technical perspective, they were willing to make changes.

Burke further says that as a result of the Hughes investigation, Hughes had asked the PRC to strengthen the weak parts of the fairing.[89]

In the paper, Burke wrote that the PRC proposed changes to what it termed the "already adequate" capabilities of the fairing. His paper continued, identifying PRC proposals for the following changes to the Long March 2E rocket's fairing:

> *a. Increased number of nose cap attachment screws from 21 to 41. Increased number of cover strip attachment screws from 12 to 23.*
>
> *Comment: These changes add strength to joints that would not need strengthening if the dome were stiff enough.*
>
> *In my opinion, these changes do not address the real problem with the nose cap design, nor do they constitute an effective "crutch" that would preclude another fairing failure. They do offer some integrity enhancement, but against loads that could best be limited by maintaining the as-designed dome configuration.*
>
> *In short, these [the fairing changes proposed by the PRC] are token changes that are easy to implement but do not preclude another fairing failure because they neither stiffen the sawcut edges of the dome halves nor stiffen the dome base frame at its discontinuities.*[90]

Burke's paper went on to discuss other technical deficiencies and questioned how Hughes could get the PRC to propose truly effective changes to the Long March 2E rocket's fairing design.[91]

Burke recalls Peter Herron, who was now Program Manager for the Optus B3 satellite, telling him that Herron had provided documentation to the PRC suggesting changes to the Long March 2E rocket's fairing during the Optus B2 failure investigation.[92]

On July 30, 1994, Herron wrote to the PRC requesting additional information about the PRC changes to the fairing. Herron showed his letter to Burke, and asked for his views on the additional modifications proposed by the China Academy of Launch Vehicle Technology. Burke says that he and others provided Herron with questions on the CALT proposed changes.[93]

On August 4, 1994, Hughes' Chief Technologist Al Wittmann wrote to Vice President Donald Cromer, stating that he believed the changes to the fairing proposed by the PRC were adequate for the upcoming Optus B3 launch.[94]

In August 1994, Burke says he attended a Hughes senior management meeting to review the changes made by the PRC to the fairing for the scheduled Optus B3 launch. The briefing slides for the meeting are dated August 8, 1994. By the time of this meeting, Burke says that Wang Dechen, the PRC designer for the Long March 2E rocket, had told him that the PRC had made improvements to the rocket's fairing. Burke further says that his review of the documents from the August 8 briefing show that the changes made were a combination of PRC ideas and Hughes ideas.[95]

According to Donald Leedle, responsible for Hughes' technology export controls, a design review in which Hughes provided information to the PRC should have required a State Department license.[96]

The Optus B3 was launched successfully on August 28, 1994, aboard a PRC Long March 2E rocket.

Apstar 2

The Apstar 2 License

On November 18, 1993, Hughes submitted an application for export license to the Bureau of Export Administration, U.S. Department of Commerce. On February 1, 1994, license number D204878 was validated. The license permitted the export of one Hughes Model HS-601 commercial communications satellite to the Asia Pacific Telecommunications Satellite Company, Ltd., Hong Kong.

The intermediate consignee was China Great Wall Industry Corporation, Beijing, PRC.

The license permitted a temporary export to China Great Wall Industry Corporation for the purpose of launch. The transaction value was $93 million.

The Commerce Department license restricted the export of detailed design, engineering, or manufacturing data to China Great Wall Industry Corporation. It further required a State Department license for activities and technical data covered by the State Department Munitions List.[97]

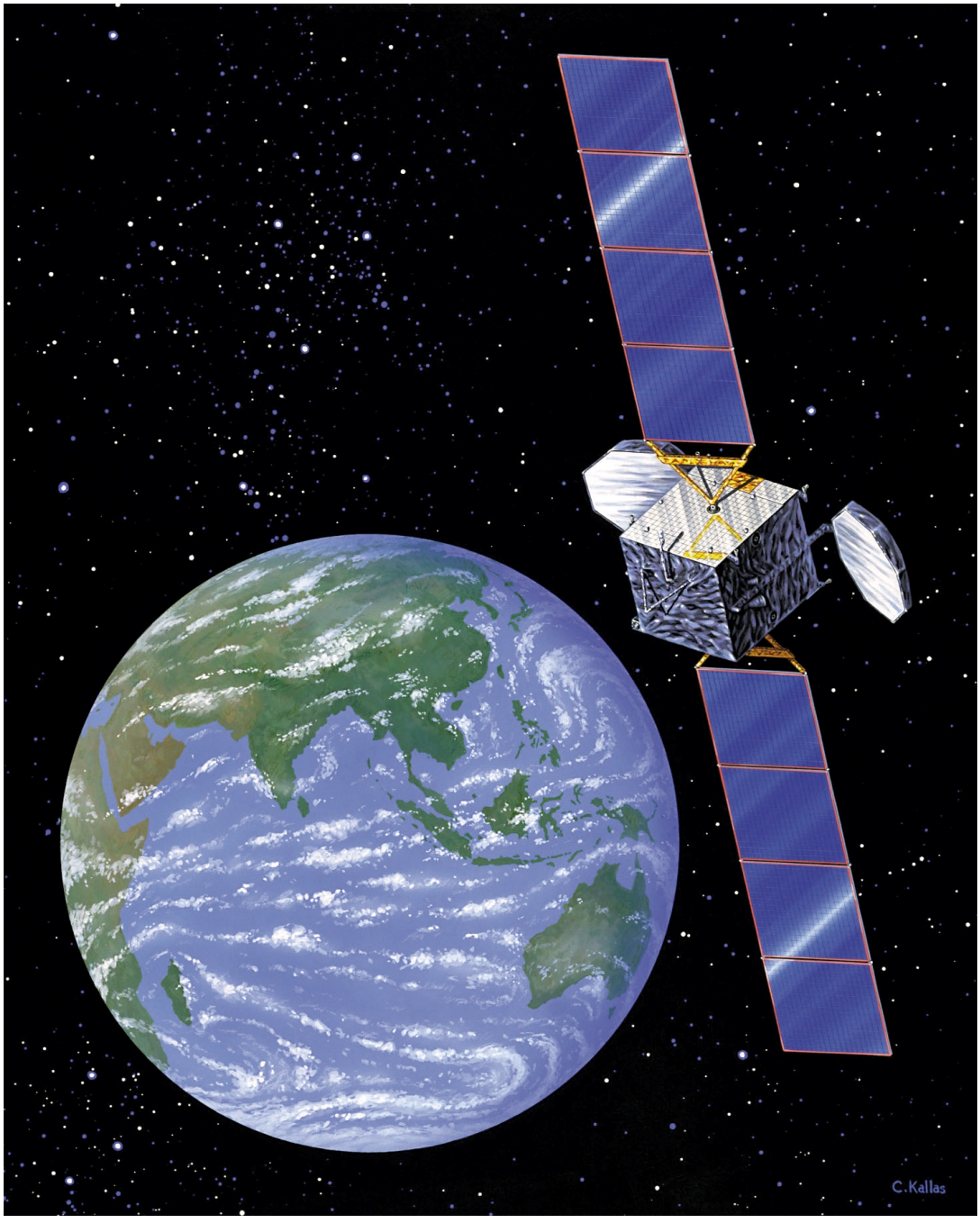
The Apstar 2 Failure

On January 26, 1995, a Long March 2E rocket, carrying the Apstar 2 satellite, manufactured by Hughes, was launched from Xichang, PRC. The Long March 2E rocket, with the satellite atop it, exploded approximately 50 seconds after liftoff.

This was the fifth flight of the Long March 2E rocket, and the second failure. The prior failure in December 1992 was of a Long March 2E rocket carrying the Optus B2 satellite, also manufactured by Hughes.

In both cases, observation of the flight data and the rocket debris indicated that an explosive force had destroyed the forward part of the rocket where the satellite and the covering fairing, which is a part of the rocket, were located.[98]

Because of similarities to the Optus B2 failure in 1992, Hughes engineers believed right away that the PRC rocket fairing had again failed.[99] Additionally, Hughes had added instrumentation to the satellite after the Optus B2 failure. The added instrumentation helped Hughes determine the cause of the failure.[100]



Dept. of Defense

Another Hughes HS-601 satellite was built for the PRC-controlled Asia Pacific Telecommunications Satellite Company Ltd. Designated Apstar 2, this satellite also failed to reach orbit when the Long March 2E carrying it crashed on January 26, 1995. Once again, Hughes assisted the PRC in fixing the problems with the Long March.

Failure Investigation Teams

Hughes Vice President Donald Cromer appointed a Failure Investigation Team, headed by Stephen Cunningham and Peter Herron, to look into the cause of the failure. Many of the participants on this investigative team, including structural specialists Al Wittmann and Spencer Ku, also had participated in the Optus B2 failure investigation.[101]

The Failure Investigation Team is described in the Apstar 2 Failure Investigation Report as follows:

> *The first team was responsible for the overall Hughes investigation and was chartered to examine any and all aspects of the failure, including the spacecraft, perigee stage, launch vehicle integration, launch vehicle telemetry, and fairing design.*
>
> *In addition, the team was responsible for all of the external interfaces, including China Academy of Launch Vehicle Technology (CALT), customers, insurance companies, and the U.S. Government.*[102]

Failure Investigation Schedule

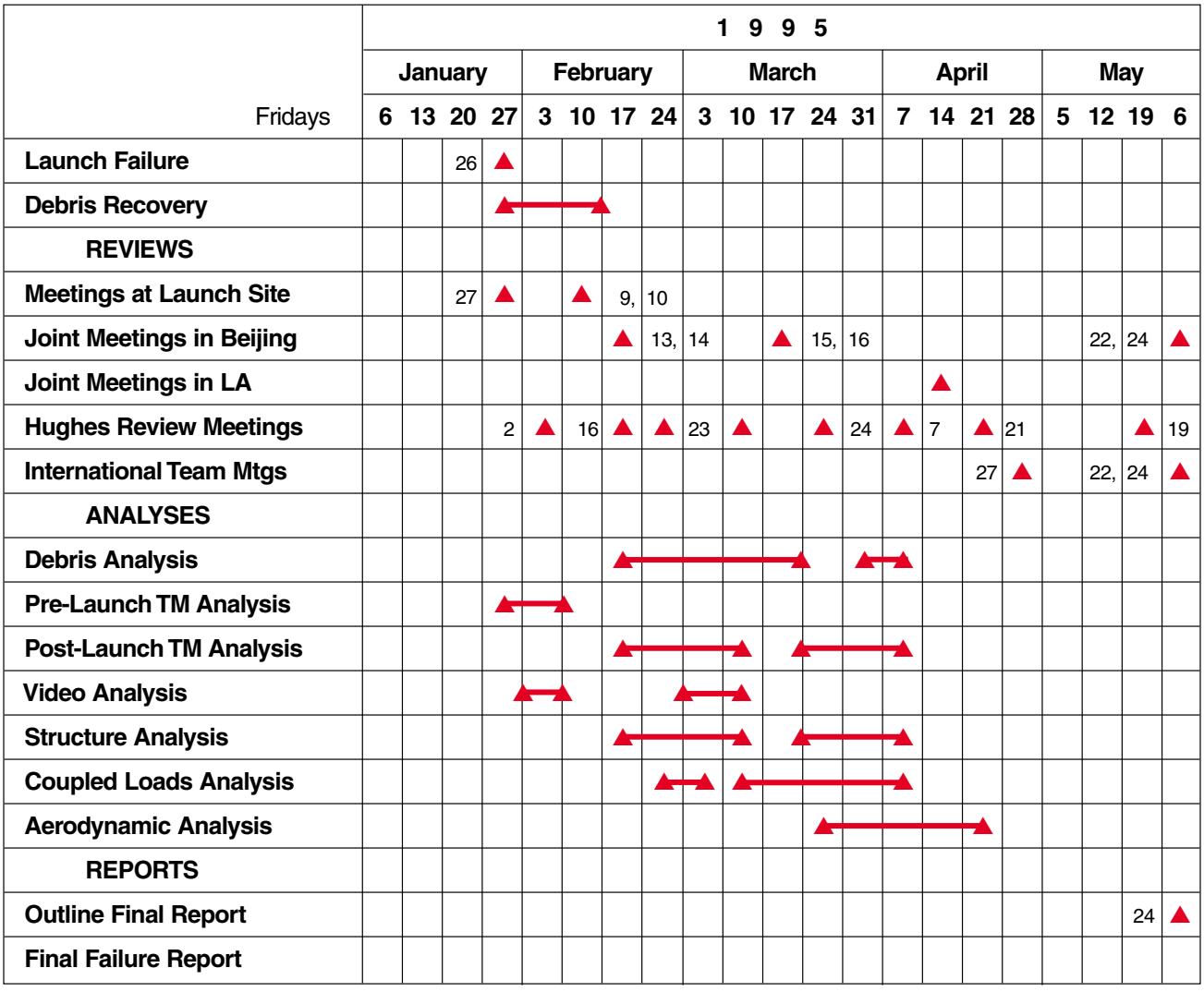
The failure investigation began immediately and continued until around June 1995. The schedule on the following page was excerpted from the Apstar 2 Failure Investigation Report.[103]

The Need For A License

At the outset of the investigation, Hughes officials considered that a State Department license might be needed in order to conduct the failure investigation even though the launch had been licensed by the Commerce Department.[104]

Soon after the failure investigation began, Hughes provided the State Department a satellite debris recovery plan for the failure. On February 3, 1995,

Hughes' Apstar 2 Investigation Schedule



The Apstar 2 failure investigation began immediately after the Long March 2E launch failure on January 26, 1995, and continued through May, 1995.

Hughes attorney Jennifer Smolker wrote to inform the Commerce Department of the launch failure, stating that future discussions with the PRC might require a State Department license and that Hughes would submit a State Department license, if necessary.[105]

On February 21, 1995, Donald Leedle, Hughes' Technology Export Control Coordinator, sent a memorandum to Apstar 2 Program Manager Mike Hersman and attorney Smolker regarding the failure investigation. Leedle's memorandum stated that the Commerce Department license only authorized the transfer of certain data.[106]

As had been done in connection with the Optus B2 failure investigation, Leedle's memorandum stated that Hughes was initiating informal communications with the State Department to determine whether a license would be required. The memorandum also stated that Hughes was awaiting data from Herron, who was working on the failure investigation, before formally applying for any such license. Finally, Leedle wrote that he had met with Commerce Department licensing officer Gene Christiansen and learned that, except for minor satellite data, all other data to be exchanged with the PRC fell under State Department jurisdiction.[107]

Christiansen says that, when Hughes officials initially approached him following the Apstar 2 launch failure, they communicated to him that they only wanted to share basic "form, fit, and function" data with the PRC. Leedle recalls that in his early discussion with Christiansen regarding information requested by the PRC, Christiansen stated that with the exception of limited satellite and telemetry data, all other PRC requested data would require a State Department license.[108]

Despite the shift to Commerce Department in 1993 of licensing jurisdiction for certain commercial satellites, the State Department still was solely responsible in 1995 for the licensing of any technical data that could improve PRC rockets.[109] Leedle, whose responsibilities at Hughes included technology export controls, acknowledges having been aware at the time that any rocket improvements required a State Department license.[110]

Leedle's statement is consistent with a document that Hughes' Dar Weston, a specialist in the International Traffic in Arms Regulations, sent to Apstar 2 Program Manager Mike Hersman on January 3, 1994. The document described the provisions

of the Apstar 1 and 2 licenses, and the restrictions in the International Traffic in Arms Regulations, and stated that no detailed design, production, or manufacturing data may be released. The document also stated that such information is controlled by the State Department, regardless of which agency has jurisdiction over the satellite, and that release of such information would require specific Office of Defense Trade Controls approval of a separate application.[111]

Leedle recalls that Hughes' Washington, D.C. representative, Joe Rougeau, made informal contact with the State Department following the Apstar 2 launch failure. He says Rougeau initiated the State Department contacts because Hughes was unsure in the early stages of the investigation whether a State Department or a Commerce Department license was needed for the investigation.[112]

The role of Hughes' Chief Technologist, Al Wittmann, in the Apstar 2 failure investigation was essentially the same as in the Optus B2 investigation. Wittmann, who had proposed the modifications to the Long March 2E rocket after the Optus B2 failure, says he recognized by looking at photographs of the Apstar 2 debris that changes to the Long March 2E rocket's fairing had been made by the PRC since Optus B2. He says the changes were obviously insufficient.[113]

Wittman said that the PRC had not implemented all the changes he had suggested for the Optus B3 launch in 1994.[114] Following the Optus B2 failure, Hughes engineers recommended reinforcing the fairing. But the Select Committee learned that the PRC chose to install additional rivets instead of structural changes. The Select Committee understands that the PRC did not implement the recommended changes to reinforce the fairing prior to the Apstar 2 launch because to do so would have been an admission of fault in the Optus B2 failure.

Wittmann's analysis immediately focused on the fairing as the cause of the Apstar 2 launch failure. He says that, had the PRC implemented all his suggested changes to the Optus B3, the Apstar 2 would not have failed to achieve orbit.[115]

According to Wittmann, he and the PRC engineers viewed the fairing structure differently. The PRC viewed the nose cone portion of the fairing as a one-piece, complete hemisphere. Wittmann, on the other hand, says the nose cone was manufactured in two sections with a slit in the middle.[116]

Commerce Department Conference

On March 3, 1995, Hughes personnel met with Commerce Department licensing officer Christiansen and his supervisor, Jerry Beiter, regarding the Apstar 2 failure investigation.[117]

Beiter was then the Chief Technology Officer at the Commerce Department. The following Hughes employees attended the meeting: Peter Herron, co-leader of Hughes' failure investigation team; Donald Leedle, Hughes' Technology Export Control Coordinator; Pat Bowers, an assistant to the Director of International Affairs, Donald Majors; and Sara Jones, an export control officer at Hughes. Bowers was responsible primarily for dealing with the State Department on licensing issues.[118] Jones was primarily responsible for coordinating licenses with the Commerce Department.[119]

The purpose of the meeting was to discuss proper licensing jurisdiction relating to the Apstar 2 failure investigation.

Beiter's recollection of the meeting is that the Hughes representatives wanted to learn what information they could discuss with the PRC related to the failure investigation. He says that information related to rockets was covered by State Department jurisdiction during this period. Beiter also recalls that at the meeting the Hughes representatives mainly wanted permission to raise topics with the PRC related to their satellite.[120]

Beiter specifically recalls advising Hughes at the meeting that any data regarding the design of the PRC rocket would require a State Department license. He also says that he has no doubt that the Hughes representatives were well aware at the time of the meeting that information related to the fairing had to be licensed by the State Department.[121]

At the end of the meeting, the Hughes and Commerce Department officials agreed, according to Leedle, that any data that could improve the PRC rocket would require a State Department license.[122]

Sara Jones, of Hughes' Washington, D.C. office, recalls attending the meeting on March 3, 1995 with Beiter and Christiansen. Jones had prepared the Apstar 2

Commerce Department application. She says she was present at the meeting because she was the Hughes Commerce Department liaison. Jones recalls that she was not conversant with the technical aspects discussed at the meeting.[123]

Jones says that the purpose of the meeting was to determine whether the Commerce Department was the appropriate licensing authority for the Apstar 2 failure investigation. She adds that an additional purpose was to determine whether the data Hughes wanted to transfer to the PRC should be licensed by the Commerce Department or the State Department.[124]

According to Jones, the meeting was mainly devoted to a discussion of the Hughes satellite as part of the failure investigation. She says that Hughes representatives were there to discuss the satellite because Hughes built the satellite.[125]

Jones stated that she was aware that Hughes was prohibited from advising the PRC about correcting problems related to its rockets. Jones advises that knowledge of this rocket prohibition was fairly standard information within Hughes.[126]

Bowers, Hughes' State Department liaison in Washington, D.C., says that any time detailed design, development, production, or manufacturing technical data was involved, a State Department license would be required, although someone had to determine whether the data was "detailed." [127]

A memorandum of this meeting with Christiansen and Beiter was prepared six days later, on March 9, 1995, by the Hughes official responsible for technology export controls, Donald Leedle. Leedle, however, says that he probably drafted it with assistance from Peter Herron, one of the leaders of the Apstar 2 failure investigation, due to the technical nature of the issues discussed.[128] Leedle's memorandum included no indication that Hughes officials at the meeting advised Christiansen or Beiter that they had any indication that the Long March 2E fairing had caused the Apstar 2 failure.

Same Fairing Failure Identified by Hughes

Hughes engineer Spencer Ku was Hughes' principal structural investigator on the Apstar 2 failure investigation.[129]

Ku had suggested fairing design fixes to Al Wittmann, Hughes' Chief Technologist, during the Optus B2 investigation in 1993.[130]

Ku says that, after arriving in the PRC to review the Apstar 2 debris in 1995, he could tell by observation that the fairing had indeed been modified since the 1992 failure.[131]

On April 7, 1995, Ku briefed Stephen Cunningham and Peter Herron, the co-leaders of the failure investigation, that as in the Optus B2 failure, his analysis was pointing to the fairing as the cause of the Apstar 2 failure. Ku says the changes made by the PRC in the number of rivets had not been adequate to prevent the Apstar 2 launch failure.[132]

On April 18, 1995, Ku wrote a memorandum to Cunningham describing how the fairing caused the Apstar 2 launch to fail.[133]

A 'Political' Business Solution, Again?

As in the aftermath of the 1992 failure, Hughes executives were quite concerned about the sensitivity the PRC attached to placing any blame on the rocket for the Apstar 2 accident. On April 4, 1995, Hughes Electronics Senior Vice President Gareth Chang wrote a memorandum to Hughes CEO Steven Dorfman regarding the Apstar 2 failure, stating:

> *As we get closer to reaching a conclusion on the cause of the Apstar 2 launch failure I am concerned that we think through all of our actions so that we minimize fallout to the greatest possible extent. I would like to make the following suggestions:*
>
> ***First, we need to personally share our findings with the Chinese leadership. A senior Hughes executive, armed with detailed scientific and technical evidence, should meet with General Shen of COSTIND and Chairman Liu of CASC before anything is said to the media.***
>
> *Statements to the media should only be made by highly qualified, senior technical experts with easy-to-follow evidence. Our case must be convincing, logical and credible. Local managers and*

PR consultants should do no more than field media questions and transmit them to California or hand out properly approved media materials.

Care needs to be taken to properly brief the insurance industry on our findings, either just before or concurrent with the media briefings.

Our findings will receive worldwide media attention and will undoubtedly be challenged by a variety of people. We need to be thoroughly prepared — and to respond in a thoughtful and professional manner.

We cannot allow this accident to damage our relationships in China — or anywhere else in the world — especially in view of several near-term satellite and regional service opportunities.

I suggest the appropriate people get together within the next few days to make sure that we have all of our ducks in a row.[134]
[Emphasis added]

As of late April 1995, Hughes had identified several problems associated with the Long March 2E fairing.

In crafting a suitable approach for the discussions, a strategy memorandum on the subject was sent on April 20, 1995. Peter Herron, in his capacity as co-leader of the Hughes failure investigation team, sent a document to Hughes Vice President Donald Cromer containing in part the following points:

- *Offer to brief CALT in advance of Int'l team meeting due to revised emphasis on fairing as cause of the failure.*
- *Emphasize to Chinese that:*
  - *— We helped them get into the business*
  - *— Improved their U.S./PRC agreement*
    - *— We need to get on with the business of launch (sic) Hughes satellites on Long March launchers.*[135]

The Commerce Department Approves Data Release to the PRC

On April 28, 1995, Peter Herron, Donald Leedle, and Tony Colucci of Hughes met again with Christiansen at the Commerce Department to bring him up to date on the progress of the Apstar 2 failure investigation.

A May 9, 1995 memorandum by Leedle regarding the meeting explains that Hughes had concluded its analysis of the failure and was requesting that the Commerce Department review the information regarding its conclusion prior to making the failure analysis available to the PRC.[136]

Notwithstanding the agreement with Christiansen in March that the State Department had licensing jurisdiction for any technical data regarding the rocket, Herron, Leedle, and Colucci presented Christiansen charts outlining the inadequacies of the Long March 2E rocket's fairing design that they proposed to present to the PRC.[137]

Hughes Technology Export Control Coordinator Leedle describes his company's intentions for this approach to the Commerce Department as follows:

> ***Q:*** *Did he [Peter Herron, Hughes' co-leader of the failure investigation] give you any indication at all that he or anyone else at Hughes intended to communicate to the Chinese that improvements were needed in the fairing?*
>
> ***A:*** *Again, we are talking about the word 'improvements.' Our results of the findings were that there were deficiencies in the design of the fairing that we thought were the probable causes of failure. That's all that I think we could comment on.*
>
> ***Q:*** *Okay. Do you recall at the time whether or not you believed that any information related to the fairing, especially if it was going to be communicated to the Chinese, required a Department of State license?*
>
> ***A:*** *No, I don't think we did.*

Leedle acknowledges being aware at the time that improvements to the PRC's rocket required a State Department license. He says, however, that he and Herron nonetheless decided to rely on Christiansen's determination of Commerce's jurisdic-

tion to approve passage of the data.[138] At the meeting, Christiansen advised that the fairing-related charts could be passed to the PRC. The charts presented to Christiansen expressed the same concerns that Hughes had expressed to the PRC in 1993 about the need for stronger rivets on the fairing. According to a Hughes official the conclusions in the charts could be helpful to the PRC, but the Defense Technology Security Administration had granted a similar approval in 1993.

The same official acknowledges that two of the fairing-related problems were not discussed with the Defense Technology Security Administration in 1993.

Hughes Tries to Get the PRC to Accept Its Findings

Hughes was still experiencing difficulty in getting the PRC to accept its findings regarding the fairing as the cause of the launch failure.

The talks between Hughes and the PRC remained at an impasse. Hughes felt that it could not afford to allow the China Academy of Launch Vehicle Technology to present its argument to the insurance companies and Hughes' customers, such as the PRC-controlled Asia Pacific Telecommunications Satellite consortium, without providing all of the evidence — especially when the evidence pointed to a failure of the Long March 2E rocket and not the Hughes satellite.

The PRC engineers, however, did not want to present any findings that led to the conclusion that the Long March 2E fairing was to blame for the failure. The PRC engineers feared that if this were to occur, then they would not be able to get insurance for future Long March launches.

In a May 14, 1995 trip report from Peter Herron to Hughes Vice President Cromer regarding a briefing Herron attended with Professor He of the PRC-controlled Asia Pacific Telecommunications Satellite consortium and other APT executives, Herron stated, in part:

- *We briefed He and Bao [Bao Miaoquin, Chief Engineer of APT] on the failue investigation for about 3 hours. He made several points re: Apstar 2R.*
- *Likely CASC [China Aerospace Corporation] reaction:*

— We know from history and experience that CASC is mistrustful of Hughes, especially due to the Optus failure . . .

— The future — is there a way out? CASC wants to sell rockets and get (I didn't say buy) spacecraft technology. They know we can hurt their rocket business, and they don't think we are serious about tech transfer.

- *My only idea for a deal for both sides is:*

— Conclude that the failure was due to wind shear (winds aloft). That actually is our conclusion. We think the fairing works (just barely) when the winds are calm. CASC would need to do the following:

— Pay us the outstanding $8 million from Apstar 2 incentives

— Buy Apstar 2R from Hughes

— Provide good design review for the (Long March) 3B and 3C fairings

- *Tilting APMT [the pending Asia Pacific Mobile Telecommunications satellite deal] our way would be a real plus.*
- *We would not provide our fairing concerns to others. We would not fly on the [Long March 2E rocket] without changes, reviews, and wind tunnel tests.*[139]

During the Hughes efforts to overcome the reluctance of the PRC to accept responsibility for the cause of the failure, Herron sent a message to his co-leader on the Hughes failure investigation team, Stephen Cunningham, on June 28, 1995. The message indicated that two Hughes employees, Shen Jun and Bruce Elbert, had conveyed a message to COSTIND's General Shen Rongjun (Shen Jun's father) regarding the fairing as causing the Apstar 2 failure. (See also the section entitled "The Role of PLA General Shen Rongjun and His Son in APMT," in the chapter *PRC Missiles and Space Forces*.)

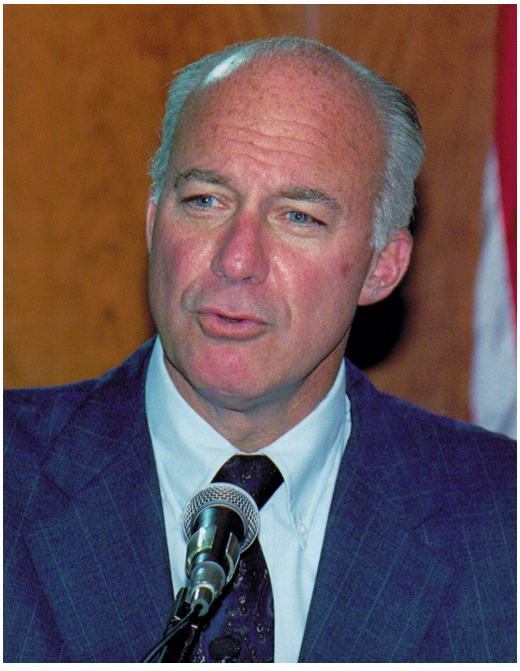
In part, Herron's message stated:

> *Last night I talked to both KC [K.C. Lang] (in Beijing) and to Bruce Elbert/Jun Shen (in Singapore).*
>
> *KC. He was bothered by the failure resolution page, because it closed out the option of compromising on the interstage or interface (between the rocket and the satellite payload) as the cause of the problem.*
>
> *He said he would make a strong push to [Hughes CEO] Steve [Dorfman] and [Hughes Electronics Senior Vice President] Gareth [Chang] to have SDD [Steve Dorfman] go to PRC to negotiate for us. He referred to an unnamed source who advised him to request Steve's presence.*
>
> *KC obviously feels we have to share the blame.*
>
> *I said we would never do that, Gen Shen had said he would not accept a B2 [Optus B2] style compromise, and that one of the attached press clips from the insurance people said the insurance industry would not, either.*
>
> *Further, it makes absolutely no sense for any Hughes exec to meet in PRC without a good basis for an agreement. (I further think the unnamed source is KC himself. He is an amiable guy who wants to please.)*
>
> *Elbert and Shen. They delivered the message to Gen Shen. He was pleased to receive it. See the above phone message. Gen Shen said he'll call a meeting as soon as he is back to try and resolve the issue. Not on the phone message (from Jun) is that Gen Shen says his people believe one thing and we believe another, and that he doesn't know how to sort it out. He is willing to admit fault if he can be convinced that the fairing failed.*[140]

The next day Cromer wrote the following letter to Hughes Electronics President Michael Armstrong, Senior Vice President Gareth Chang, and Hughes CEO Dorfman:

> *I believe we are now at the crossroads for resolving the Apstar failure investigation. Attatchment 1 is a summary of where we are and recommended next steps. We have provided Attachment 1 to K.C. Lang to share with key people in Beijing to stimulate a response and get their input.*
>
> *Bruce Elbert was in Singapore with Jun Shen and they have already talked with Gen. Shen. He was pleased to get the input and said he would call a meeting as soon as he is back to try and resolve the issue. Gen. Shen says his people believe one thing and we believe another, and that he doesn't know how to sort it out. He is willing to admit fault if he can be convinced that the fairing failed. He also said that he was willing to work with Mike [Armstrong], Gareth [Chang], Steve [Dorfman] and Don [Cromer] to try and resolve the dilemma.*
>
> *I have also attached a copy of our Independent Review Team Report (Attachment 2). It clearly supports our internal team's conclusions about the fairing being the most probable cause of the failure.*
>
> *Given all this, I believe we need to be firm and insistent that they acknowledge 'what is' and clear the air so we can get on with our business. The insurance community and our customers are not about to let us skate on this issue again. Any level of outside probing will quickly reveal all the facts of this accident and its close resemblance to the Optus B2 failure. Our investigation results will speak for our case. It is a well documented and substantiated investigation that clearly exonerates the spacecraft. I will keep you informed as this last critical phase unfolds, and will probably need your assistance to force a resolution in our favor.*[141]

Associated Press



Associated Press

Hughes President and Chief Executive Officer Steven Dorfman (*left*) led Hughes' launch failure review that resulted in unlicensed transfers to the PRC of information directly applicable to improving PRC rockets and missiles. Hughes deliberately acted without the required State Department license. C. Michael Armstrong (*right*), then Chairman and Chief Executive Officer at Hughes Electronics Corp., wrote to National Security Adviser Samuel L. Berger: "Efforts by the State Department to keep commercial communications satellites on the State Department Munitions List should not be allowed to succeed."

By July 1995, Hughes had definitively concluded that the failure of the Long March 2E rocket on the Apstar 2 launch was caused by the rocket's fairing. Specifically, Hughes determined that the aerodynamic forces from the velocity of the rocket, combined with the winds aloft and high wind shear, ripped the fairing apart.

PRC Minister Liu Jiyuan, Director of China Aerospace Corporation, reacted emotionally to statements by Hughes indicating that the Long March 2E fairing was the cause of the failure. Minister Liu, who is influential in awarding communications satellite contracts in the PRC, said that China Aerospace Corporation would never do business with Hughes again.

CIA Analyst Visits Hughes

On July 19, 1995, an analyst from the Central Intelligence Agency's Directorate of Intelligence visited the Hughes facility in El Segundo, California, known as the "High Bay," which is an assembly and testing facility for communications satellites.[142] The CIA analyst was researching a draft National Intelligence Estimate relating to the impact of technology transfers on the PRC's military capabilities.[143]

The CIA analyst recalls that during a tour of the High Bay, he had an opportunity to talk to a Hughes engineer about the Apstar 2 failure investigation.

During this conversation, the CIA analyst began to be concerned that, as part of Hughes' launch failure investigation, technology that could improve the PRC's Long March rockets would inevitably be transferred to the PRC.[144]

In discussing the failure investigation, the CIA analyst says the Hughes engineer mentioned that Hughes has provided information to the PRC that related to methods and computer modeling to reduce rocket vibration, because vibration may have been a contributing factor to the Long March 2E failure.[145]

The CIA analyst says he believed that any improvements in this area would certainly assist the PRC in improving the performance of its ballistic missiles.[146] When he asked the Hughes engineer whether the information that Hughes was providing to the PRC might contribute to the improvement of PRC rockets, the Hughes engineer advised that this was Hughes' intent.

But Hughes officials advised, the engineer said, that all required coordination with the Commerce Department had been undertaken.[147] The CIA analyst also recalls the following regarding his discussion with the Hughes engineer about the cause of the Long March 2E rocket failure during the attempted launch of the Apstar 2 satellite:

> *Well, the discussion was sort of concluded with a general view by the individual [the Hughes engineer] that the system had failed because of external pressure [on] the fairing, which could have been due to aerodynamic loading and/or vibrational loading, but that conclusions were based largely*

> *on modeling with imprecise or insufficient information about the fairing itself, insufficient telemetry data.*
>
> *There had been a recommendation to the Chinese to conduct additional tests, including wind tunnel tests.*
>
> *[T]hey had some ground-based data on the wind velocity as a function of altitude. They were recommending the Chinese try to replicate that in the wind tunnel.*[148]

The CIA analyst's recollection of his discussion with the Hughes engineer in 1995 seems consistent with the reports Hughes provided to the Commerce Department, which cited wind shear (aerodynamic loading) and vibrational (buffeting) factors as the cause of the Long March 2E failure.[149]

The reports Hughes provided to the PRC after approval by the Commerce Department's Christiansen stated in part:

> *The initial failure occurred in the LM-2E fairing and was due to some combination of:*
>
> * * *
>
> *Aerodynamic forces, buffeting, and/or aeroelastic effects on the launch vehicle during the transonic phase [that is, accelerating through the sound barrier] accentuated by winds aloft.*

Regarding the potential transfer of technology, the CIA analyst recalls the following:

> *. . . I had been told actually by the Hughes people that their export license established restrictions on the flow of technology to China in that it regulated the kinds of interactions that they could have, the sort of proscripted interactions.*
>
> *And what this engineer described to me was a break from that path, that people rolled up their sleeves at this point and just got together in a free-flow exchange.*[150]

The CIA analyst recalled this about his conversation with the Hughes engineer regarding the "coupled loads" analysis that Hughes had conducted with the PRC:

. . . [The Hughes engineer] indicated that he had fully described the analysis, the process – not only the process that he had done, but the process that they [the PRC] should do.

In other words, the Chinese had done analysis on their own and Hughes had done analysis on its own, and for reasons which weren't fully clear to me, the two came together and they shared the results.

So it wasn't a one-way thing, it was a two-way thing; and they discussed who was right and who was wrong, but also what could be done better in the future.[151]

A lot of it's just basic engineering physics, but code – the key here, we're talking about a big chunk of software on a big computer. The code was Hughes' proprietary code.

. . . the Chinese had told Hughes what the maximum vibrational load that the satellite would face under any normal launch circumstance would be. Hughes believed that their satellite could survive under that maximum load, but it was close. It was far in excess of the load estimated by the Russians or the French, and certainly way in excess of the U.S. And so if they exceed that by much, that could be a problem. So part of his effort was to make sure it didn't exceed that or did exceed that.[152]

A 'Consolidated Solution'

On July 23, 1995, Hughes and the PRC released a joint press statement regarding the Apstar 2 failure. The statement was signed by PRC Minister Liu and Hughes CEO Dorfman.

In the statement, Hughes and the PRC essentially agreed to disagree over the cause of the failure. Hughes cited high winds affecting the fairing as the most probable cause of the accident. The PRC cited a satellite and rocket interface problem. The release, the text of which follows, was signed by Dorfman and Liu:

JOINT PRESS RELEASE ON
APSTAR 2/LM-2E FAILURE INVESTIGATION
BY CHINA GREAT WALL INDUSTRY CORPORATION
AND HUGHES SPACE AND
COMMUNICATIONS INTERNATIONAL, INC.

23 July 1995

Apstar 2, an HS-601 communications satellite built by Hughes Space and Communications International, Inc. (HSCI), was launched by an LM-2E launch vehicle provided by PRC Great Wall Industry Corporation (CGWIC) at Xichang Satellite Launch Center on 26 January 1995. After a normal flight for about fifty seconds, an explosion occurred and resulted in the total loss of both the launch vehicle and the satellite.

After the failure, experts and engineers from CGWIC and HSCI have exerted extensive, scientific and earnest investigations for the past six months to pinpoint the cause of the failure.

Both CGWIC and HSCI confirm that the launch met the requirements stated in the Apstar 2/LM-2E Interface Control Document.

CGWIC and HSCI concluded in their reports that there are two (2) possible causes for the failure:

1. Under the shear wind aloft conditions in winter season, the resonance exerted due to the unique interface of the satellite and the upper stage with the launch vehicle caused local structural damage to the satellite.

2. Under the shear winds aloft conditions in winter season, the fairing of the launch vehicle suffered local structural damage.

In the spirit of being responsible to the customers and the space insurance community, CGWIC and HSCI will work

together to eliminate the above mentioned possible causes of failure and to enhance the monitoring of shear wind aloft before launch.

CGWIC and HSCI reaffirm their long term and friendly cooperation and are determined to continue with confidence to expand the cooperation in areas of mutual business interests.[153]

Final Failure Investigation Report Released to the PRC by the Commerce Department

On August 15, 1995, Peter Herron, co-leader of the Hughes failure investigation team, wrote a letter to Commerce Department licensing officer Gene Christiansen enclosing the following documents:

- **The final Hughes Long March 2E Apstar 2 failure investigation report**
- **The Hughes Independent Spacecraft Review Team Final Report**
- **An executive summary of the Hughes failure investigation**

The cover letter mentioned that Herron and Donald Leedle, Hughes' Technology Export Control Coordinator, planned to meet with Christiansen on August 17 to discuss releasing these documents to the PRC.

The Executive Summary of the Hughes failure investigation stated:

As part of the Apstar 2 failure investigation, an independent review team was formed with a charter to review all aspects of the failure and provide an interface with the International Oversight Team. The six member team, led by Ernest La Porte, has had an extensive experience base in launch vehicles, spacecraft, fairings, and launch operations. The review period was from February to June 1995.

The major findings are that the spacecraft and interstage were not the cause of the failure, but the fairing is the most probable cause.

It is clear from the telemetry record that the LM-2E fairing suffered catastrophic failure at a time when the payload was intact and undamaged. The LM-2E booster fairing failed due to deficient design with respect to aerodynamic loads caused by high winds and wind shear.

The most probable failure scenario was initiated by high aerodynamic loads initially causing the fairing downrange vertical separation line to open and the dome to crack. As the fairing continued to collapse, it caused the spacecraft structure to fail, crushing the propellant tanks. The resulting fire caused the destruction of the spacecraft and the secondary destruction of the booster.

The most probable root cause of the failure is the deficiency in the fairing longitudinal split line design requirements and/or design. The causes of the Optus B2 failure in December 1992 and the Apstar 2 failure in January 1995 are identical.

There are a number of concerns relative to the design of the LM-2E fairing. These include the rivet strength of the separation zipper, the nose cap split line and the hammerhead fairing aerodynamic shape. There are additional concerns regarding the launch vehicle to spacecraft interfaces, such as design of the launch vehicle Marmon clamp separation band, fairing vent area, flying a high angle of attack and lack of detailed launch weather criteria.

The major recommendation is for [Hughes] to require major design reviews for new launch vehicles such as Proton, LM-3B, and Delta 3. Also [Hughes] should require the launch vehicle supplier to be responsive, cooperative and open to requests for design and test data.[154]

In response, Christiansen sent a Commerce Department form to Leedle on August 24, 1995 indicating that Hughes was authorized to release the Apstar 2 reports to the PRC. The form, called a Commodity Classification Form, stated:

> *These two reports and executive summary have been reviewed and determined to contain no design or production data specific to the spacecraft, the launch vehicle or the interface of these two systems.*[155]

The Commodity Classification form also stated that the data simply documented the findings of the PRC's telemetry and utilized a logic sequence to fix the probable cause of the failure, without instructing how to redesign the fairing.[156]

'THE FAIRING IS PART OF THE LAUNCH VEHICLE'

A rocket's nose cone, which protects the satellite inside, is known as a fairing. The same nose cone, if used on a ballistic missile to protect the nuclear warhead payload, is called a shroud.

Whether the launch vehicle is a rocket or a ballistic missile, the function of the nose cone is specialized to protect the payload — satellite or nuclear warhead — from external aerodynamic loads, vibration, noise, temperature extremes, and other environments that may be encountered as the vehicle is launched and accelerates through the atmosphere.

In the case of rockets, the fairing protects the satellite. In the case of ballistic missiles, the shroud would most likely be used to protect multiple independently-targeted reentry vehicles (MIRVs). (See the *Technical Afterword* to this chapter for a description of the similarities between the design and construction of the fairing for a rocket and a shroud for a ballistic missile.)

In 1995, Hughes argued to the Commerce Department that the fairing was part of the satellite and, therefore, Hughes' advice to the PRC regarding the fairing did not require a State Department license. A Commerce Department official, without asking any other U.S. Government agency, agreed.

The Select Committee requested that the Department of Defense, the Department of State, the Department of Commerce, CIA, and NASA provide responses to the question:

Although Sara Jones of Hughes' Washington, D.C. office was responsible for applying for Commerce Department licenses, it was Leedle who went directly to Christiansen to obtain the Commerce Department Commodity Classification approval for the Apstar 2 report. Jones states that Leedle had not handled a Commerce Department commodity classification himself in the past.[157]

Christiansen acknowledges that he knew, at the time he developed the Commodity Classification approval, that data concerning PRC rockets required a State Department license.[158]

Christiansen also testifies that Hughes was prohibited by the Commerce Department Commodity Classification Approval from providing data to the PRC

"Is the fairing part of the launch vehicle, or part of the satellite?" Their answers are summarized as follows:

Defense: "The fairing is part of the launch vehicle. It is designed and manufactured by the launch provider to encapsulate payloads (including, but not limited to, satellites). The fairing must be designed as an integral part of the launch vehicle system as its structure, in many respects, determines the success of the launch." [134]

State: "The Department considers the fairing to be an integral part of the space launch vehicle. The forward end of a space launch vehicle typically has a payload fairing, which protects both the satellite and the space launch vehicle from aerodynamic loading and heating during the launch vehicle's ascent through the densest part of the atmosphere." [135]

Commerce: "Fairings are regarded as part of the launch vehicle. Under U.S. implementation of multilateral controls, fairings are under the export jurisdiction of the Department of State." [136]

CIA: "The CIA considers the payload fairing to be part of the space launch vehicle because the fairing is needed to fly the vehicle and satellite through the atmosphere. Furthermore, the fairings are typically designed and built by the launch vehicle provider, not the satellite manufacturer." [137]

NASA: "The fairing is routinely acquired as a component of the launch vehicle service." [138]

related to technical design, rocket production, or anything related to the rocket. He adds that it was also incumbent upon Hughes to limit the scope of its discussion with PRC personnel, and to determine whether a State Department license was required.[159]

Christiansen acknowledges that he chose not to initiate any discussion or review of the matter with State Department or Defense Department officials before granting approval for Hughes to provide the fairing information and report to the PRC. The basis for this, he says, is that the Hughes information contained no design or production data. Christiansen acknowledges that his approval was a mistake, since the Hughes report represents an in-depth analysis of the design deficiencies of the fairing, and the executive summary discusses design changes that should be made to the fairing for future PRC launches.[160]

The PRC Long March rocket was still on the State Department Munitions list when Christiansen granted the approvals. Nonetheless, Hughes officials asked Christiansen if he would approve the materials for release, and he did.

Implementing the 'Consolidated Solution'

On October 17, 1995, Hughes employees K.C. Lang and Nissen Davis prepared a trip report regarding a visit by Hughes Electronics CEO Michael Armstrong and Senior Vice President Gareth Chang to the PRC between October 9 and 12. The report stated, in part:

> ***[Meeting with] GEN. Shen Rongjun, Deputy Director, Commission of Science Technology and Industry for National Defense (COSTIND)***
>
> ***Launch Failure Investigation.*** *Both sides need to examine and correct all possible causes. Shen has insisted on destruction testing the new LM-2E fairing design and hoped Hughes would do likewise for its new interface design. CMA [C. Michael Armstrong] said he and Chang would take personal*

responsibility for a consolidated solution communicated to insurance industry in Munich at end of October. [Armstrong] will convene meeting in L.A. on Oct 17, the day he returns to US, to achieve complete team agreement on 'consolidated solution.' Chang and Herron are principals to insure coordination.

[Meeting with] Min Liu Jiyuan, President of China Aerospace Corporation (CASC)

Launch failure. *[Armstrong] related agreement with Shen that consolidated solution is best. Chinese should accept Hughes engineering conclusions and Hughes should accept theirs. Joint approach should be presented to market and insurance community. Liu agreed but worried whether Hughes people will honor agreement. Before statement goes to Munich it should be tested in Beijing with HSC. [Armstrong] assumed personal responsibility for accountability, named G. Chang and Peter Herron to manage project for him.*[161]

By December 1995, Hughes' Independent Review Team had concluded that the probable cause of the failure was the fairing's longitudinal split line design requirements, the design itself, or both. The causes of the Optus B2 failure in December 1992 and Apstar 2 failure in January 1995, they found, were identical.

Hughes and the PRC agreed on a solution to address all concerns. Hughes agreed to modify the interface adapter, and the PRC agreed to strenghten the fairing and enhance the monitoring of high altitude wind conditions.

The PRC still refused, however, to accept the findings of Hughes' Independent Review Team that the fairing was the cause of the failure.

Moreover, the international insurance community expressed some skepticism regarding the PRC's claim that it had corrected the problem with the fairing. This was because the PRC stated that its repairs were completed in summer 1995, well before the final failure analysis was completed.

U.S. Government Actions Following the Apstar 2 Launch Failure

On January 26, 1995, the day of the Apstar 2 launch failure, U.S. Air Force Major Victor J. Villhard prepared a report stating that there were no technology safeguards in place for the Apstar 2 failure investigation.[162] He also stated that, since Apstar 2 had been exported under a Commerce Department license, no U.S. Government monitoring to prevent technology transfer had been required.

The memorandum outlined the possible technology gains for the PRC that could result from the lack of guidelines.[163]

Mark N. Rochlin was a Defense Technology Security Administration monitor for Motorola Iridium launches in the PRC in 1995. On May 31, 1995, he wrote a memorandum for the record in which he described incidents of technology transfer that he observed in Beijing in March and April 1995.[164] The memorandum stated:

> ***SUBJECT: Long March Accident Investigation***
>
> 1. *During my last two trips to Beijing in March and April, I had the opportunity to hear failure investigation briefings presented by China Great Wall Industries [sic] Corp and the China Academy of Launch Vehicle Technology (CGWIC and CALT). These briefings were presented to launch service buyers other than Hughes, and were in significant detail.*
>
> 2. *It is my opinion, based upon the briefings and from discussions with Mr. Gao Rufei (CGWIC) that* ***the technical exchange that has already occurred with Hughes exceeds the conditions of the license issued to Hughes by the Department of Commerce.*** *Future discussion necessary to continue the investigation will grow increasingly technical and will be similarly out of bounds. It has been revealed by Space Systems Loral, that they have been asked to perform a role in the investigation and that they are concerned about*

the character of the work being performed and their requirement to adhere to established guidelines. It follows that it is necessary for the United States Government to ensure compliance with the conditions of the license and the appropriate investigative agencies become involved.

3. *CGWIC and Space Systems Loral were reminded of the Government to Government Agreement that provided for tech safeguards and of the personal liability to adhere to established guidelines.*

//Signature//
Mark N. Rochlin
Lieutenant Colonel, US Army
Assistant for Aerospace Technology

CC:

Col Alexandrow, DTSA *[Defense Technology Security Administration]*
Mr. Maloof, DTSA

Col Oldenburg, Dept of State, OES/STH *[Office of Oceans and International Environmental and Scientific Affairs/Office of Science, Technology, and Health]* [165] [Emphasis added]

Rochlin says that, during the meeting in Beijing, he was told that Loral had been approached by Hughes to participate in the Apstar 2 failure investigation.[166] Rochlin says that it was apparent to him from the comments of Loral's Nick Yen that Hughes had already transferred significant technical information to the PRC in the Apstar 2 investigation and Loral was concerned about the technical areas Hughes was getting into, because he knew that only a Commerce Department license was in effect for the Apstar 2.[167]

Rochlin also says that Gao Rufei of China Great Wall Industry Corporation had mentioned the coupled loads analysis on Apstar 2. Based on the nature of the information Gao discussed, Rochlin believed that a State Department license was required.

Rochlin says he told a Loral representative and a representative of China Great Wall Industry Corporation that he believed that Hughes had already acted outside the scope of its Commerce Department license. He reminded both representatives that they should adhere to the U.S./PRC government-to-government agreements, and that they were personally liable for violations of the International Traffic in Arms Regulations.[168]

Rochlin says he retired from the Army several days after writing the memorandum, so he does not know whether the Defense Technology Security Administration took any action based on it. However, he says he did discuss the incidents and the information in the memorandum with the agency's Director, David Tarbell, and the Deputy Director, Peter Sullivan. He further recalls giving a copy of the memorandum to Michael Maloof, who was the Defense Technology Security Agency point of contact for coordination with enforcement agencies, to whom Rochlin believed such information might be referred for investigation.[169]

Defense Department Assessments of Damage to National Security

On December 7, 1998, the Department of Defense completed an initial assessment of the January 1995 Apstar 2 launch failure. The assessment was based on the Hughes Apstar 2 reports that had been provided to the Defense Department by the Commerce Department in June 1998.[170]

The Defense Department assessment concludes that the technical information provided to the PRC by the Hughes Apstar 2 failure analysis can be applied to either PRC rockets or ballistic missiles. The Defense Department considers that the assistance rendered to the PRC by Hughes in the 1995 Apstar 2 failure investigation was a "defense service," and clearly beyond the scope of the export jurisdiction of the Commerce Department.[171]

According to the Defense Department, "the conclusions outlined in the Hughes/Apstar materials provided to the PRC (and reviewed by the Defense Department for this assessment) were sufficiently specific to inform the PRC of the

kinds of launch vehicle design or operational changes that would make the Long March 2E (and perhaps other launch vehicles as well) more reliable," [172] and could assist the PRC military in development of a more reliable fairing for use with ballistic missiles.[173]

Damage to National Security from the Apstar 2 Failure Investigation

The Hughes Failure Investigation Team included several sub-teams that were assigned the following areas:

- **Spacecraft debris**
- **Material properties**
- **Video analysis**
- **Telemetry**
- **Coupled loads**
- **Structures**
- **Aerodynamics**

Of these sub-teams, the last three most clearly involved rocket design considerations.

The following account of the activities of these three sub-teams is taken directly from the report of the Hughes Failure Investigation Team.

Coupled Loads: This sub-team reviewed all of the coupled loads analysis information that was available for the Long March 2E rocket/HS-601 satellite combination. They compared the flight data from the satellite accelerometers that have flown on the Long March, the Atlas, and the Ariane. They traveled to Beijing to work beside the CALT engineers to review and participate in the Coupled Loads Analysis methodology. They expanded the standard satellite dynamic model (normally good to 75 Hz) to be valid up to 100 Hz.

Structures: The structures sub-team analyzed the strength requirements and capabilities of the satellite, the interstage, and the rocket's fairing. They performed stress analysis and buckling analysis on the primary structure elements based on

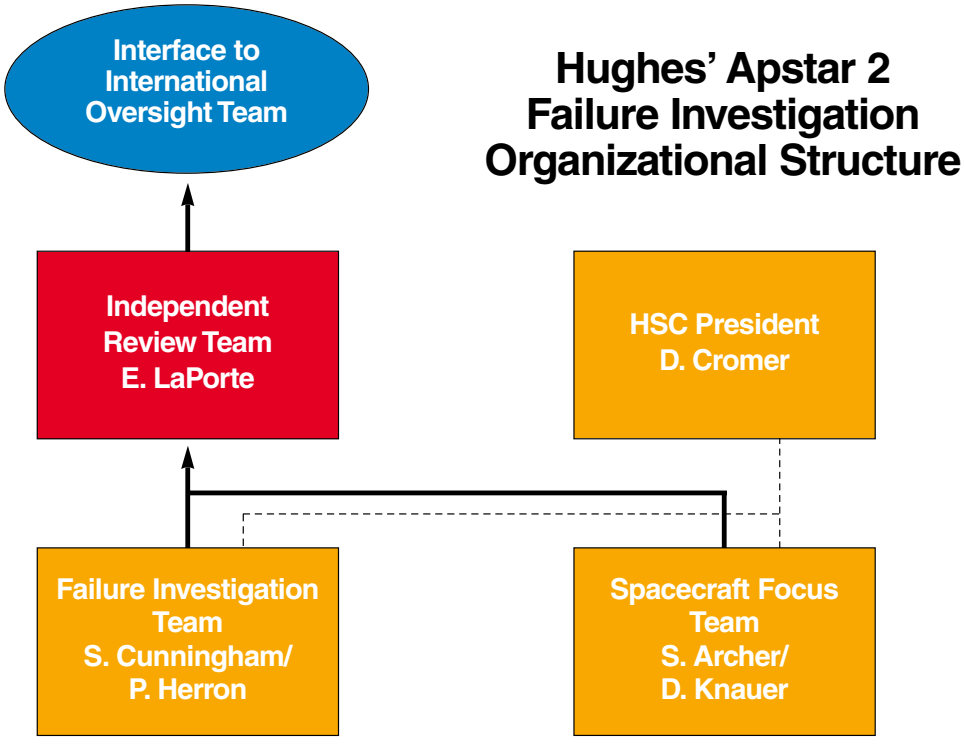
detailed knowledge of the satellite and on design information supplied by CALT. They analytically determined the strength requirements and capabilities of the rivets in the fairing zipper. They analytically determined the deformation characteristics and the strength of the dome structure. They analyzed the capabilities of the satellite and rocket clamp bands.[174]

Aerodynamics: The aerodynamics sub-team was formed in order to understand the forces applied to the fairing which, in turn, are transmitted to the satellite. This team used the expertise of the Hughes Missile Systems Group to determine the flow field around the fairing, the pressure distribution, and the resulting forces and moments on the fairing and launch vehicle. This team also reviewed the NASA SF8001 guidelines that classify the Long March 2E fairing configuration as "separated, unstable." The guideline strongly recommends a comprehensive wind tunnel test program.[175]

The Defense Department believes it is likely that the Failure Investigation Team's seven sub-teams provided some of the principal interfaces between Hughes and the PRC in the preparation of individual analytical pieces of the decision tree approach to defining the likely root cause of the failure. In one case, for example, Hughes reported that a sub-team worked "beside" PRC engineers "to review and participate in coupled loads analysis methodology" (quotation in original).[176]

Each of these sub-teams carried out technical efforts that involved identifying the causes of failure of the Long March 2E fairing, and may have contributed directly to redesign of the fairing to bring its structure up to adequate levels of strength. Moreover, there is indication in the Hughes report on the launch failure that not only the results of Hughes team and sub-team work, but also the methods and know-how based on experience in the areas of airload determination and structural analysis and design, may have been imparted to the PRC.

At a minimum, it appears evident from the Hughes Failure Investigation Team report that the PRC member of the International Oversight Team could have had access to all of it. Indeed, such access is guaranteed by the International Oversight



Team's charter. The statement in the report that the Coupled Loads Analysis sub-team "traveled to China to work beside the CALT engineers to work and participate in the Coupled Loads Analysis methodology" indicates a much more focused channel for possible technical information exchange with the PRC.

The conclusion reached by the Hughes Failure Investigation Team was that the initial failure of the Long March 2E launch of the Apstar 2 occurred in the rocket fairing. This failure was caused by the aerodynamic forces, buffeting, and aeroelastic (that is, interactions between structural dynamics and airloads) effects that are encountered as the rocket enters the transonic phase of flight. These effects were accentuated by the winds aloft and wind shear that were high on the day of the launch.

The Hughes Failure Investigation Team also noted the importance of the fact that the 1992 failure of the Long March 2E carrying the Optus B2 satellite occurred under the same (winter) wind conditions that prevailed at the time of the 1995 Apstar 2

launch failure of the same PRC rocket. The Hughes team pointed out that the three successful Long March 2E launches all took place when such wind conditions did not prevail.

It was further concluded on the basis of structural analyses that the fairing failed either in the rivets of the fairing zipper or in the fiberglass nose dome. Hughes engineers actually made a detailed stress analysis of the redesign of the rivets in the fairing zipper.

Damage to National Security From the Sharing of Coupled Loads Analysis

Coupled loads analysis simulates and assesses the interplay of the loads on the rocket during flight, including interaction between the satellite and the rocket which are stacked one on top of the other.

This analysis is based on a finite element model, a mathematical representation of the specified grid points that define the physical body of the satellite. Finite element analysis is the analysis of structural stress about the satellite body grid points.

Coupled loads analysis combines the satellite and rocket models for loads analysis. Information contained in the Hughes/Apstar materials indicates that, based on that analysis, Hughes learned that the PRC coupled loads analysis was deficient.

As with satellites and rockets, coupled loads analysis and finite element analysis are applied in the design and testing of missiles to the interaction of the components of a missile and warhead during launch.

The Defense Department believes it is reasonable to infer that, during the close collaboration between Hughes and PRC engineers, Hughes imparted to the PRC sufficient know-how to correct the overall deficiencies in their approach to coupled loads analysis and the PRC's finite elements model.[177]

Much of the work during the investigation appears to have been done in the PRC in close collaboration with PRC experts. Hughes clearly was concerned about the serious flaws in PRC modeling and analysis of aerodynamic loads on the Long March rocket's fairing. According to the Hughes/Apstar materials, among the lessons Hughes said it learned was that it cannot rely exclusively on the PRC to perform coupled loads analysis.

Damage to National Security From Providing the PRC With Information Concerning Deficiencies in the Fairing, and Resultant Improvements to PRC Rockets and Ballistic Missiles

The Defense Department determined that, according to the Hughes/Apstar materials, deficiency in PRC design of the rocket fairing was cited as the most likely "root cause" of the Long March 2E failure. Hughes' conclusions highlighted numerous areas of concern focusing on improving the Long March rocket design.

The conclusions included:

- **Concerns about the fairing design**
- **The rivet strength of the zipper**
- **Weaknesses in the nose cap split line**
- **The shape of the fairing**

There were also concerns about certain Long March rocket interfaces (such as the design of the clamp separation band) and inadequate vent area in the rocket's fairing.[178]

The Defense Department found that, over the course of about five months in early 1995, Hughes conducted a broad and in-depth investigation that involved significant and detailed technical interchanges between Hughes and PRC experts.[179] These interactions specifically addressed a full range of possible causes for the failure that included a comprehensive analysis of the Hughes satellite and the PRC rocket fairing and flight loads.

The investigation's conclusions that were provided to the PRC were very specific and identified the need for modifications in the Long March rocket fairing design and in PRC launch operations.[180]

The PRC made several changes to the Long March 2E fairing in 1995 to address possible failure causes, including:

- **Structural changes to strengthen the fairing**
- **Improved coupled loads analysis**
- **Tighter winds-aloft launch go/no-go criteria, to prevent launches in winds above a specific threshold**

Further, the PRC modified the Long March 2E guidance system by adding a wind-bias trajectory compensation to limit the Long March 2E's angle of attack.

All of the above changes by the PRC directly addressed Hughes' recommendations conveyed to the PRC in the course of the failure investigation.

The Defense Department assessment concluded that:

> *[T]he [PRC] modifications in the LM-2E fairing, coupled loads analysis, and launch operations apparently addressed the problems because the PRC successfully launched two non-Hughes commercial communications satellites on LM-2E vehicles in November and December 1995.*
>
> *Although the LM-2E has not been used since then, the lessons learned from the APSTAR 2 investigation are directly applicable to fairings on other launch vehicles, including those used to boost PRC military satellites. . .*
>
> *[A]lthough it is possible that the PRC may be able to transfer the benefits of this launch failure investigation to its ballistic missile programs, the utility to those programs would be limited largely to development of a more reliable fairing for use with advanced payloads on military ballistic missiles.*

Other Information Learned
By the PRC, and Defense Department Reaction

The Hughes investigation provided the PRC with details about the satellite design and some manufacturing/inspection practices to prove that the satellite was not responsible for the failure, and that a faulty Long March rocket fairing design was the likely root cause of the failure.

The joint investigation also provided the PRC with insight into U.S. diagnostic techniques for assessing defects in rocket and satellite design.

The Defense Department concluded that there was no evidence of any limits on the Apstar 2 investigation imposed by the Commerce Department or any other U.S. Government agency. As a consequence, the PRC and Hughes engaged in technical exchanges, such as those concerning coupled loads analysis and finite elements analysis, that would allow the PRC to gain specific insight into specific rocket design, operational problems, and corrective actions.[181]

In addition, the Defense Department report stated that

> *. . . based on DOD's experience monitoring technical interchange meetings and related activities in connection with foreign launches of U.S. commercial satellites, it is reasonable to conclude that during the course of the five-month Hughes investigation there were significant interactions with the PRC of a highly technical and specific nature that are not reflected in the Hughes/Apstar materials reviewed by DOD.*[182]

The Defense Department assessment also noted that its findings and conclusions are "necessarily preliminary in nature," given the incompleteness of the information available. For example, the Defense Department assessment properly noted the assistance a Hughes "subteam" provided in coupled loads analysis, but also that "the precise nature of the analyses performed and the composition of skills of the team members cannot be ascertained from the Hughes/Apstar materials reviewed by the Defense Department." [183]

State Department Assessments of Damage to National Security

The State Department very recently completed its assessment of the assistance provided by Hughes to the PRC. The text of the State assessment is reproduced on the following pages:

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MEMORANDUM
December 18, 1998

SUBJECT: Review of APSTAR II/Long March 2E Failure Investigation Data

We have completed our review of the documents associated with the APSTAR II/Long March 2E launch failure, and offer the following analysis for your review.

SUMMARY

The launch failure investigation began in January 1995 immediately following the failed launch of the Chinese LM-2E space launch vehicle (SLV) with the Hughes Space and Communications (HSC) designed APSTAR II communications satellite payload onboard. The investigation involved the formation of several groups of technical experts by both the Chinese and Hughes. Additionally, both parties contracted an independent investigation team of private consultants and space industry experts. Throughout the course of the investigation, Chinese and Hughes personnel engaged in an extensive exchange of technical data and analyses. There were no US Government monitors overseeing these activities.

After a thorough review of the data provided to the Office of Defense Trade Controls (DTC), this office has concluded that:

> The Chinese were deficient (to varying degrees) in the areas of anomaly analysis, accident investigation techniques, telemetry (TLM) analysis, coupled loads analysis (CLA), hardware design and manufacture, testing, modeling and simulation, and weather analysis.
>
> HSC [Hughes] assisted the Chinese in identifying their shortcomings in these areas, through provision of detailed technical analyses and critiques of Chinese failure analysis. The interaction between HSC [Hughes] and the Chinese on the APSTAR II failure investigation resulted in significant improvement to the Chinese spacelift program and contributed to China's goal of assured access to space. The

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> lessons learned by the Chinese are inherently applicable to their missile programs as well, since SLVs and ICBMs share many common technologies.

Our review of the APSTAR II failure investigation centered upon documentation provided by Hughes Space and Communications to DTC. The data included memoranda, faxes, technical reports, etc. Thus, our final assessment is based on solely upon the exchange of written information between Hughes personnel and their Chinese counterparts. Accordingly, we have categorized our analysis by the kinds of work Hughes performed for the Chinese.

ANOMALY ANALYSIS/ACCIDENT INVESTIGATION

The differences between Hughes Space and Communications and Chinese approaches to conducting the accident investigation were substantial. The Hughes teams followed an in-depth and exacting process for conducting and documenting an accident investigation. They provided descriptive accounts of failure analysis, highlighted with explanations to include empirical evidence, fault elimination, deductive reasoning, etc. Throughout the course of the investigation, Hughes identified faults with Chinese practices and techniques.

> HSC [Hughes] identified that the LV [launch vehicle] clamp band was not seated correctly during flight, owing to slippage possibly caused by vibrations and the use of a lubricant on the band. It recommended the Chinese review this area prior to future launches. (Hughes Failure Investigation Report, para 4.3.3, July l995).

> HSC [Hughes] identified a possible design flaw in the venting system of the payload fairing (PLF), compared the system to western standards, and recommended the Chinese review this area prior to future launches. (Hughes Failure Investigation Report, para 4.3.3, July 1995).

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HSC [Hughes] identified a possible design flaw in the nose dome of the fairing. Analysis of the PLF debris from both the APSTAR II and OPTUS B2 uncovered similarities in the probable failure of the nose dome. (Hughes Failure Investigation Report, para 4.3.3, July 1995).

HSC [Hughes] identified the effect of wind shear on both the APSTAR II and OPTUS B2 launches. Moreover, they identified western standards for command and control to remedy the negative effects of wind velocity on a vehicle in flight. (Hughes Failure Investigation Report, para 4.3. 1, July 1995).

HSC [Hughes] conduct of debris investigation was superior to Chinese analysis. Numerous rebuttals to Chinese analysis of launch debris identified inaccuracies, misrepresentations, and incomplete analyses of debris which were critical to fault identification. HSC [Hughes] results were supported by technical drawings, photographs, modeling, etc. (HSC Response to CALT Video, 8 May 95: Hughes Independent Spacecraft Review Team Final Report, July 1995; Hughes Failure Investigation Report, July 1995).

TELEMETRY ANALYSIS

Telemetry (TLM) analysis helps re-create the events leading to an anomaly — one of the most critical elements of any accident investigation. Throughout the course of this investigation, Hughes Space and Communications provided detailed explanations of its TLM analyses and identified probable errors in Chinese analyses.

HSC [Hughes] identified the TLM data as "the most important source of information regarding the failure." HSC [Hughes] analysis of TLM data directly pointed to failure of the PLF in-flight for APSTAR II, as well as to the previous in-flight failure of the

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OPTUS B2. HSC [Hughes] laid out the history of the flight via TLM analysis, identifying "77 points" (i.e. significant events) which were critical to its analysis. (HSC APSTAR II Failure Presentation to CGWIC, 13 Feb 95; Hughes Failure Investigation Report, para 4.1.1, 4.3.3, Section 5, July 1995).

HSC [Hughes] identified Chinese TLM analysis as deficient in several areas: the Chinese did not identify LV [launch vehicle] trajectory corrections due to wind shear effects; incorrectly interpreted accelerometer data; failed to identify a probable anomaly with the clamp band; and missed a probable fault with the PLF venting process. (HSC APSTAR II Failure Presentation to CGWIC, 13 Feb 95; HSC APSTAR Failure Review: Status Report, Pt II, 12-13 Apr 95; CALT APT Failure Investigation Report, 25 Jun 95; Hughes Independent Spacecraft Review Team Final Report, para 3.3.1, 3.3.3, 3.4.2, 3.4.3, 3.4.6, July 1995).

COUPLED LOADS ANALYSIS

The Hughes Space and Communications coupled loads analysis (CLA) team "spent extended time in Beijing with the CALT CLA team to understand and validate CLA methodology." In the course of these exchanges, Hughes shared modeling and calculation data, made comparisons to Western standards, and identified areas of concern in the Chinese CLA modeling processes. Both Hughes and the Independent Oversight Team (IOT), hired by Hughes and the Chinese, found discrepancies in Chinese CLA. Indeed, the Independent Spacecraft Review Team provided a telling insight into Chinese CLA efforts by stating, "…there was definite confusion in understanding the static and dynamic envelopes for the complete stack assembly."

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> HSC [Hughes] conducted joint re-analysis of CLA after reviewing the flight's TLM data. In several cases, it either re-affirmed or did not concur with pre-flight modeling conducted by the Chinese.
>
> This included sharing of modeling, calculations, methodologies, etc. (HSC APSTAR II Failure Investigation to CGWIC, 13 Feb 95; LM-2E Failure Module, 8 May 95; Hughes Failure Investigation Report, para 4.1.2, July 1995).
>
> HSC [Hughes] specifically identified concerns with Chinese CLA early in the investigation: "Low fidelity of CLA mode definition … Uncertainty in loads." (APSTAR II Failure Review, Other Concerns, 12 Apr 95).
>
> HSC [Hughes] compared and contrasted Chinese CLA with Western aerospace analyses of Ariane and Atlas. (HSC APSTAR II Failure Briefing, May 1995).
>
> An IOT member, when referring to possible failure of the PLF, stated, "… (failure) could be the combination of incorrect design loads … (the Chinese) need further understanding of the impact both of static and dynamic loads upon the payload fairing…" (Memorandum from Mr. Ernest L. LaPorte to HSC and CGWIC, 14 Jun 95).

HARDWARE DESIGN/MANUFACTURING

Hughes uncovered design and/or manufacturing flaws in the payload fairing, and determined that they directly contributed to the failure of two Chinese space launch vehicles. Additionally, Hughes identified possible problems with the Chinese manufactured launch vehicle clamp band and interface adapter.

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The Structures Team conducted technical analyses on the PLF and identified flaws in the rivets used to secure the zipper area of the PLF (Hughes Failure Investigation Report, para 3.2.2, 3.4, 3.5.3, 4.2.1, 4.3.3, July 1995).

The Aerodynamics Team reviewed Chinese wind tunnel modeling and testing. It provided comparison with and reaffirmed open-source information from NASA, which identified design flaws in the PLF (Hughes Failure Investigation Report, para 3.2.2, 3.5.4, 4.3, 4.3.2, July 1995).

The Structures Team identified possible design flaws and possible improper installation of the launch vehicle clamp band (Hughes Failure Investigation Report, para 3.2.2, 3.5.3, 4.3.3, July 1995).

HSC [Hughes] recommended, that the Chinese conduct a thorough review of quality control procedures prior to any anomaly analysis investigation (Hughes Independent Spacecraft. Review Team Final Report, para 3.3. 1, July 1995).

HSC [Hughes] identified possible material and design faults with the Chinese manufactured interface adapter, the Environment and Interfaces Team (EIT), analysis of TLM supported this conclusion. Additionally, EIT identified a possible anomaly in Chinese ground operations procedures for the installation of the clamp band (Hughes Independent Spacecraft Review Team Final Report, para 3.3.1, 3.4.3, 3.4.6, July 1995).

HSC [Hughes] provided a critical assessment of the Chinese designed interface adapter an inadequate design by HSC standards (Hughes Independent Spacecraft Review Team Final Report, Lessons Learned, July 1995).

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> (Also: see ANOMALY ANALYSIS/ACCIDENT INVESTIGATION above, for other design/manufacturing issues).

TESTING

Hughes made recommendations for improvements to Chinese testing methodologies and verified results of Chinese tests of hardware.

> HSC [Hughes] recommended vibration testing of the spacecraft - launch vehicle adapter stack for future launches to preclude clamp band anomalies; the EIT supported this as well (Hughes Independent Spacecraft Review Team Final Report, para 3.3.1, 3.4.6, July 1995).
>
> Hughes personnel suggested: "that for future applications, with this or new launch vehicles, a vibration or modal test be performed combining the adapters, perigee stage and spacecraft to resolve loads, modes, deflections and accelerometer testing." (Hughes Independent Spacecraft Review Team Final Report, July 1995).

In October 1995, following the conclusion of their joint investigation with Hughes, Chinese technical experts publicly made a series of commitments to their insurers to improve their spacelift program. In each case, the Chinese had previously (through June 1995) concluded that no problems existed. Hughes, on the other hand, insisted from the outset of the investigation that there were problems, and provided the technical analyses to support their claims.

> PAYLOAD FAIRING: To strengthen their design, the Chinese made the following changes to the PLF: added bolts to the nose cap; included a support beam for the dome; added a frame and-seal cap between the dome pieces; switched to a manual locking

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mechanism for a hatch door. Additionally, the Chinese increased their complement of ground tests and changed their ground operating procedures for the PLF.

WIND SHEAR ALOFT: The Chinese planned to increase monitoring and measuring times; prepared to modify SLV trajectory based upon modified wind prediction models.

COUPLED LOADS ANALYSIS: Stated plans to strengthen payload and launch vehicle compatibility analyses.

CONCLUSIONS

Hughes assistance directly supported the Chinese space program in the areas of anomaly analysis/accident investigation, telemetry analysis, coupled loads analysis, hardware design and manufacturing, testing, and weather analysis. Moreover, the assistance provided by Hughes is likely to improve the standing of the Chinese in the commercial launch market, as they make improvements in spacelift reliability and performance.

Hughes personnel knew the Chinese had problems in their space program. The Failure Investigation Team concluded that the Chinese launch failure hypothesis (provided independently from and prior to the Hughes failure report) failed to identify several key anomalies with the launch vehicle. Thus, we conclude Chinese anomaly analysis was not up to Western standards.

Comparing the APSTAR II failure to the January 1995 [actually February 1996] *failure of a Long March-3B (INTELSAT payload) reveals similarities between the two cases. In both instances, the investigation teams identified common themes with regard to Chinese deficiencies in launchoperations, anomaly analysis, modeling and simulation, manufacturing, and quality control, etc. However, we conclude the APSTAR II investigation*

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provided more detailed assistance to the Chinese than the more general support provided during the Long March 3B investigation. The two investigation reports, centering on different variants of the Long March vehicle family, offer strong evidence that the Chinese spacelift program suffers from poor reliability. The reports reveal that U.S. contractors knew where the Chinese program suffered from inadequacies. Moreover, the contractors often corrected errors in incomplete or incorrect analysis or filled in gaps where the Chinese simply lacked the technical knowledge.

Essentially, the APSTAR II failure investigation (and to some extent, the investigation of the Long March 3B) served as a tutorial for the Chinese, allowing them to improve on areas in which their spacelift program was weak. The Lessons Learned section of the Independent Spacecraft Review Team final report also offers commentary on the serious concerns HSC [Hughes] had with China's spacelift program: "HSC should never compromise on doing a coupled loads analysis. If politics, government constraints or vendor issues do not permit the analysis then it is our recommendation that this is not a suitable launch."

The impact and extent of any damage to U.S. national security as a result of the Hughes accident investigation into the APSTAR II launch failure is difficult to quantify. However, we believe the assistance provided by Hughes to China will prove to be significant to the degree it contributes to the increased reliability of their launch vehicles. The recent record of Chinese space launches in fact shows an improvement in reliability. The longer term effect of increased launch reliability will be to improve the rate of successful deployment of Chinese satellites and, in turn, to facilitate China's access to space for commercial and military programs.[184]

(end of memo)

Damage to National Security Identified by The Select Committee's Technical Consultant[185]

A senior technical consultant to the Select Committee, Dr. Alexander Flax, concluded that although the configuration of ballistic missile fairings (or shrouds) may be substantially different from the fairings employed on rockets, the methods for determining quasi-steady as well as vibratory and acoustic noise-generated flight loads would be the same.

The vibration spectrum of resonant frequencies varies as the launch trajectory is traversed. This complex of changing resonant conditions must be analyzed in relation to the changing aerodynamic, acoustic, buffeting, and wind shear forces that come into play along the launch trajectory. The resulting loads are resisted by the intricate structure of the fairing, and getting the distribution of loads and stresses right is not a simple task.

There is as much experience-based art as science in the successful application of the well-established numerical analysis and design methods available. It was the benefit of this experience and know-how that Hughes engineers could have made available to their PRC counterparts.

The Hughes engineers who worked on the failure investigation obviously believed that the PRC lacked an adequate understanding of buffeting loads. The final report of the Focus Team stated:

> *It also appears that [Hughes] had a limited understanding of CALT's [the China Academy of Launch Vehicle Technology's] capabilities in the area of aerodynamic buffeting analysis/ loading. They are in the launch business, they know their job, and it's their problem cannot be an acceptable position in future use of Chinese launch services.*

More explicitly, the report stated, "It is known that CALT [the China Academy of Launch Vehicle Technology] did not adequately take buffeting into account."

The Hughes engineers also believed the arbitrary split at the interface between satellite and rocket in the responsibilities for coupled load analyses led to errors in the analyses. The following strong view is expressed in the report:

> *[Hughes] should never compromise on doing a coupled load analysis. If politics, government constraints, or vendor issues do not permit the analysis then it is our recommendation that this is not a suitable launch.*

Thus, the PRC experience and knowledge learned during the Apstar 2 failure investigation about the aerodynamic and other loading conditions and environments on rocket fairings, and the structural design process taking these conditions into account, would stand them in good stead in developing fairings (or shrouds) for ballistic missiles. Shrouds and fairings, even if differently configured, employ many common types of sub-components, including supports, rivets, domes, and explosive bolts.[186]

Fairings or shrouds are not common on single-warhead land-based ballistic missiles, although there are exceptions. Many submarine-launched ballistic missiles (SLBMs) use fairings. While no currently deployed PRC intercontinental ballistic missiles use fairings, it is likely that the next generation of PRC intercontinental ballistic missiles or SLBMs will employ fairings or shrouds.

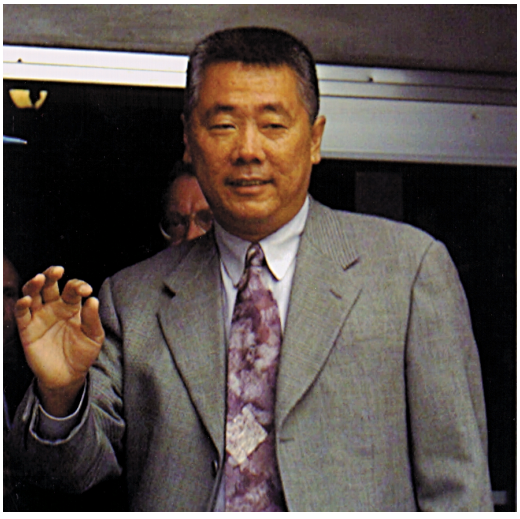
In 1997, the PRC was reportedly developing two intercontinental ballistic missiles, which could possibly carry multiple independently targeted reentry vehicles (that is, multiple warheads on a single ballistic missile). While experts do not believe that the PRC is currently developing multiple independently targeted reentry vehicles (MIRVs) or multiple reentry vehicles (MRVs), they do agree that the PRC has the technical capability to develop missiles with MRV or MIRVs within a period of years of a decision to do so.[187]

If the PRC decided to deploy MRV or MIRVed missiles, it is likely that the payloads would be protected by a shroud, since only one MIRVed missile, the Russian SS-20, does not employ a shroud.

Charlie Trie, the PRC, and Hughes Electronics

Yah Lin "Charlie" Trie, a former Little Rock, Arkansas restaurateur and friend of President Clinton, was indicted on January 28, 1998 and charged with participating in a conspiracy by, among other activities, attempting to obtain benefits by circumventing the Federal Election Campaign Act.[188]

In the early 1990s, Trie formed an import-export business known as Daihatu International Trading Corporation, and used that business to make frequent trips to the PRC.[189] He arranged for at least eight delegations of PRC government officials and others to visit the United States.[190] Trie visited the White House at least 23 times from 1993 through 1996.[191]



Associated Press

In May 1996 Yah Lin "Charlie" Trie, a former Little Rock, Arkansas restaurateur and friend of President Clinton, received $100,000 from the CP Group, shareholders in the PRC-controlled APT satellite program. A search of his Little Rock, Arkansas office by U.S. Law Enforcement officials yielded a handwritten note in Mandarin on stationery from a Hong Kong hotel. The note included the entries: "Hughes, U.S. Government, Export Control Licenses, Bribery Problem — Government Official."

Trie, his family, and his businesses contributed a total of $220,000 to the Democratic National Committee between 1994 and 1996. During that same period, Trie and his businesses received a total of approximately $1.5 million by wire transfer from foreign sources.

In May 1996, he received $100,000 from the CP Group, shareholders in the PRC-controlled Asia Pacific Telecommunications consortium and the Apstar satellite program. Trie was also involved in extensive fundraising activities, including fundraising for the Presidential Legal Expense Trust, which later decided to return all of Trie's donations.[192]

Trie's political activities paved the way for his appointment to the Commission on United States/Pacific Trade and Investment Policy, which was to advise the President "on the steps the United States should take to achieve a significant opening of Japan,

China and other Asian and Pacific markets to U.S. business."[193] In a March 1996 letter to the President, Trie expressed concern over U.S. intervention in the tense situation that arose from military exercises being conducted by the PRC near the coast of Taiwan.[194]

Justice Department officials have obtained from a search of Trie's Little Rock, Arkansas, office handwritten notes in Mandarin on stationery from the Hong Kong International Hotel. No analysis of the handwriting has been provided to the Select Committee. The note contains approximately 16 separate items. The first three items read as follows:

HUGHES U.S. GOVERNMENT

EXPORT CONTROL LICENSES

BRIBERY PROBLEM — GOVERNMENT OFFICIAL

The Select Committee attempted to contact Trie through his attorney, but Trie refused to provide the Select Committee with any information or testimony because of his upcoming trial. Similarly, the Justice Department has declined to provide the Select Committee with any further information.

Further Investigation Warranted

Further investigation is warranted along several paths, including:

- **The kind of information that may have been passed to the PRC beyond what appeared in the materials reviewed by the Defense Department**
- **The application, if any, of coupled loads analysis to improving the accuracy and range, as well as the reliability, of PRC ballistic missiles**
- **The likelihood that the PRC will in fact incorporate this know-how into their future missile and space programs**

The Defense Department report also calls for further investigation of the details of the information provided by Hughes.[195]

NOSE FAIRINGS ON ROCKETS AND BALLISTIC MISSILES

The front end of a rocket is usually a structure, known as a *fairing* or *shroud*, that serves to protect the satellite being launched from the external aerodynamic loads, vibration, noise, temperature extremes, dirt, dust, rain, snow, and micrometeorites that may be encountered as the satellite is launched and accelerates through the atmosphere into space.

The design of a fairing is governed by a myriad of factors including its weight, contribution to overall vehicle drag, structural strength, cost, and the size and shape of satellites it is to enclose.

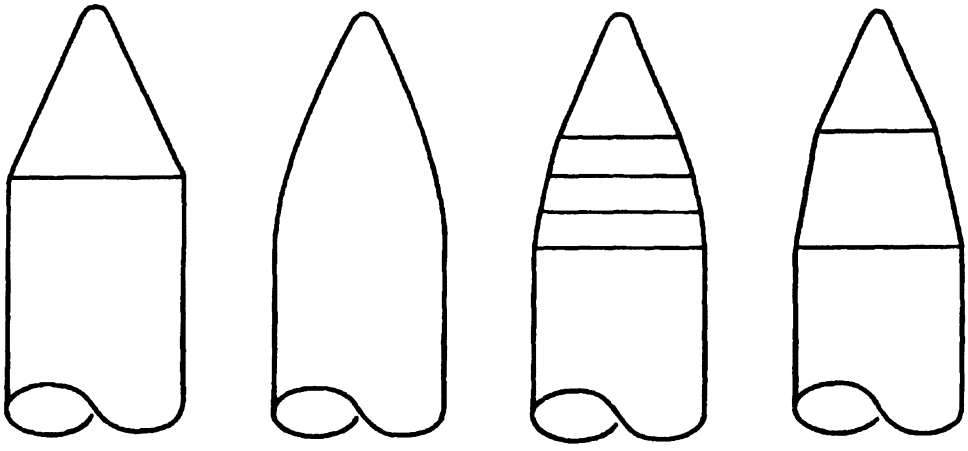
The relationship between fairing shape and just two of these factors — weight and drag — for a class of fairings of simple geometrical shape is shown above.

The question of whether minimum weight or minimum drag should be given greater emphasis depends on the details of the launch. If the fairing can be dropped early in the flight, low drag is more important. If satellite payload protection is needed through a large part of the launch trajectory, then the weight of the fairing becomes more significant in launch performance.

Given a specific fairing design, and a specific launch trajectory, the weight-drag tradeoff influences the altitude at which the satellite is separated from the rocket.

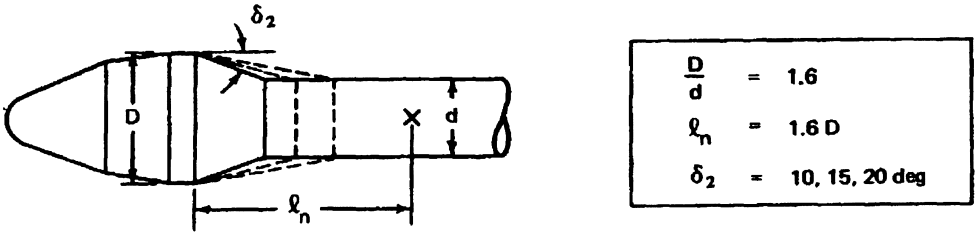
Cost and ease of manufacturing can also be factors in shaping fairings. The following graphic shows the evolution of fairings for the NASA Saturn rockets. The evolution was toward a single frustum/cone, and it occured on the basis of compromises of effects on vehicle performance with volume enclosed, fairing manufacturability, and cost.

U.S. Fairing Development Over Time



Fairings developed for NASA's Saturn rockets evolved toward a single frustum/cone as a compromise among such factors as the effects on vehicle performance, manufacturability, and cost.

Overshadowing these factors, however, is the requirement that the fairing be shaped to enclose the payload being launched. For large payloads, such as the current generation of communication satellites, the satellite containment requirement often leads to the use of hammerhead fairings (see illustration below) in which the maximum diameter of the fairing exceeds the diameter of the uppermost stage of the rocket. This type of fairing is subject to severe buffeting loads as it traverses the transonic speed region due to unstable aerodynamic flow separation and shock waves in the transonic region.



For large payloads such as today's communication satellites, hammerhead fairings are often used. The maximum diameter of the fairing exceeds the diameter of the uppermost stage of the launch rocket, and is subject to severe buffeting loads as it traverses transonic speeds.

Land-based ballistic missiles with single warheads usually do not have fairings (or shrouds, as such components are more often called in missile terminology) covering the warhead. However, ballistic missiles with multiple reentry vehicles (MRVs) and multiple independent reentry vehicles (MIRVs) usually do have shrouds, although with advanced nuclear weapon design, the density of the payload is high and the volumes to be enclosed are usually smaller than for communication satellites. Consequently, hammerhead designs do not seem to have been used for the shrouds on ballistic missile systems carrying multiple warheads.

However, it should not be assumed that single warhead missiles never use fairings, while multiple warhead missiles always use them. The U.S. Minuteman II ICBM faired its single, relatively blunt reentry vehicle in order to present a lower radar cross section at a time when a widely-deployed Soviet ABM system seemed to be in the offing. Moreover, this fairing was not shed until well into atmospheric reentry.

Another possible use of fairings would be to protect road-mobile missiles from the rigors of the environments to which they would be exposed, although covers that would be discarded before launch would be more likely.

Finally, in some cases, a shroud or partial shroud in the form of a nose cap might be used for drag reduction in the case of a blunt reentry vehicle. Again, the likelihood of hammerhead fairings being used for this purpose is not great.

In the case of the U.S. Trident submarine-launched ballistic missile, because of the limited length of the launch tubes, the shroud is blunt on launch, but a device known as an "aerospike" is extended forward from the front end to reduce drag in flight through the atmosphere.

Thus, the most likely PRC ballistic missile use of fairings would be on missiles equipped with MRVs or MIRVs, or on a submarine-launched missile. If the United States goes forward with a National Missile Defense program, the motivation to employ either MRVs or MIRVs may become compelling for the PRC. In the same vein, the incentives to employ various types of penetration aids (chaff, balloons, decoys, distributed jammers, etc.) will increase, and shrouds may be used to protect them and their deployment mechanisms.

Although the detailed configuration of ballistic missile fairings may be substantially different from the fairings used on rockets, the methods for determining quasi-steady as well as vibratory and acoustic noise-generated flight loads, and for designing the structure to resist these loads, would be the same.

Thus, the PRC experience and knowledge of the aerodynamic and other loading conditions and environments on rocket fairings, and the structural design process taking these conditions into account, would stand them in good stead in developing fairings (or shrouds) for ballistic missiles.

While the basic theories and experimental methods for determining flight loads and environmental conditions on rockets are in the public domain, the successful application of these theories and methods in design often requires know-how and engineering judgment derived from experience. Thus, for example, a recent text (*Space Vehicle Mechanics, Elements of Successful Design,* Peter L. Conley, Editor, John Wiley & Sons, Inc., New York, 1998, pg. 589), in discussing the qualification factors to which rocket components are to be designed and tested, cites some differences between the military and NASA standards, and then goes on to say:

> *MIL-STD 1540 and NASA-STD 7001 both state that the document should be tailored by the user to fit a particular space vehicle program. Even these definitive documents leave room for debate.*