IG-99-036

AUDIT REPORT

X-38/CREW RETURN VEHICLE OPERATIONAL TESTING

September 20, 1999

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Space Administration

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Acronyms

CRV	Crew Return Vehicle
ISS	International Space Station
NPG	NASA Procedures and Guidelines

*W September 20, 1999

TO: M/Associate Administrator for Space Flight
AA/Director, Lyndon B. Johnson Space Center

FROM: W/Assistant Inspector General for Auditing

SUBJECT: Final Report on the Audit of X-38/Crew Return Vehicle – Operational Testing
Assignment Number A9900200 Redacted Report*
Report Number IG-99-036

The subject final report is provided for your information and use. Please refer to the Results in Brief for the overall results. Our evaluation of your response is incorporated into the body of the report. Your comments on a draft of this report were responsive to the recommendations. The recommendations will remain open for reporting purposes until corrective action is completed. Please notify us when action has been completed on the recommendations, including the extent of testing performed to ensure the corrective action is effective.

If you have questions concerning the report, please contact Mr. Dennis E. Coldren, Program Director, Human Exploration and Development of Space Audits, at (281) 483-4773, or Mr. Len Diamond, Audit Program Manager, at (407) 867-4531. We appreciate the courtesies extended to the audit staff. The final report distribution is in Appendix C.

[original signed by]

Russell A. Rau

Enclosure

cc:
B/Chief Financial Officer
B/Comptroller

* We have redacted portions of this report due to references to deliberative process information. The redacted passages do not affect the validity of this report or management's response.

G/General Counsel
JM/Director, Management Assessment Division

bcc:
AIGA, IG, Reading Chrons
JSC/BD5/Audit Liaison Representative
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NASA Office of Inspector General

IG-99-036 **September 20, 1999**

A9900200

X-38/Crew Return Vehicle – Operational Testing

Introduction

The NASA Office of Inspector General has performed an audit of X-38/CRV project management effectiveness, including flight-testing (Assignment Number A9900200). Our overall objective was to evaluate the effectiveness of X-38/CRV project management. We noted a condition regarding operational testing of the CRV that warrants timely action by management. Additional details on the objectives, scope, and methodology are in Appendix A.

As part of an international memorandum of understanding, the United States agreed to provide a crew-return capability for the International Space Station (ISS) to be used in the event of crew injury or illness, ISS failure, or Space Shuttle unavailability. To meet the commitment, NASA authorized the X-38/Crew Return Vehicle (CRV) Project, for which the Johnson Space Center (Johnson) is the lead center. The planned cost of the X-38/CRV Project is $90 million (Space Flight Advanced Projects funds) for the X-38 segment and about $1.1 billion (ISS Program funds) for the CRV segment.

Results in Brief

NASA has made no provision for an operational test of the CRV to determine its safety for human space flight.[1] Instead, the Agency plans to human rate the CRV[2] based on a space flight test of the X-38,[3] certification by the CRV production contractor, and ground tests.[4] Although three independent review groups[5] have expressed concerns about human rating the CRV without operational testing, NASA has not planned or provided for CRV operational testing. NASA prefers to make a decision on CRV operational testing following the X-38 space flight test. While NASA plans to conduct an X-38 space flight test and other risk mitigation activities, the criticality of the CRV to the safety of ISS crewmembers requires immediate contingency planning for CRV operational testing.

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[1]A CRV operational test would include a production vehicle being carried by a Space Shuttle Orbiter to the ISS, docking and remaining on the ISS for about 3 months, and deploying unmanned from the ISS to Earth.

[2]The NASA term for this rating process is "human rating."

[3]An X-38 space flight test would include a test vehicle being carried by a Space Shuttle Orbiter to Earth orbit, remaining in orbit for about 2 days, and deploying unmanned from orbit to Earth.

[4]None of the plans include a test flight of a CRV.

[5]The independent groups were the NASA Advisory Council/Cost Assessment and Validation Task Force, Independent Program Assessment Office, and Aerospace Safety Advisory Panel.

Background

The X-38/CRV uses a lifting body concept[6] that includes a disposable deorbit module for atmospheric entry to 23,000 feet and a parafoil for the final descent and landing for as many as seven crewmembers. The X-38/CRV Project is in early development, with the acquisition phase scheduled to begin in September 1999 and the first CRV scheduled to be operational in May 2004. NASA is designing, building, and flight testing the X-38 but plans to select a contractor to build the CRV. The Project Manager reports to Johnson's Director of Engineering for the X-38 segment and to the ISS Program Manager for the CRV segment.

Operational Vehicle Testing Needs to be Assessed

Finding. NASA has not planned or provided for CRV operational testing that may be necessary to human rate the CRV. Specifically, the X-38/CRV Project Office plans do not include flight testing of a production vehicle. Also, the Project Office had not assessed the probability of production vehicle testing, and until May 19, 1999, had not formulated decision dates and criteria needed if production vehicle testing is performed. Further, the Project Office has not identified the risk, financial resources, or requirement for one or more Space Shuttle flights if operational testing is ultimately needed to rate the CRV for human flight. The Project Manager stated that an operational test had not been planned because there was no baseline requirement for one, sufficient basis existed that human rating might be achieved by an X-38 space flight test, and sufficient time remained to address the issue. The CRV must be deployed to permit the full complement of seven crewmembers on board the ISS and to assure their safe return to Earth, together, if necessary. CRV operational testing could delay the current schedule for CRV deployment and, therefore, needs to be thoroughly and promptly assessed.

NASA Requirements

Human-Rating Requirements. Requirements for all future spacecraft, including the CRV, that are intended to carry humans are contained in policy document Johnson-28354, "Human-Rating Requirements," June 1998. A general requirement is that, whenever possible, the flight test program must include the entire mission profile. Safety and reliability requirement No. 6 states that the program shall be designed so that cumulative probability of safe crew return over the life of the program exceeds 99 percent.

Risk Management. NASA Procedures and Guidelines (NPG) 7120.5A, "NASA Program and Project Management Processes and Requirements," April 3, 1998, contains criteria for risk management. Risk management is conducted to identify risks; analyze their impact; prioritize, develop, and plan for risk mitigation; and track risks. Primary risks, that is, those having both high probability and high impact or severity, require consequence development, probability

[6]The U.S. Air Force developed the lifting body concept in the 1960's during its X-24 Program.

estimation, cost impact, schedule impact, and other program management actions. The ISS Program Office has developed a risk management process through which it implements the requirements of NPG 7120.5A.[7]

Human-Rating Plan. The Project Office plan for human rating the CRV requires the Phase 1[8] contractor to develop a plan for certifying that the CRV meets all specified design and performance requirements. The Phase 1 contractor must also provide an assessment of the CRV design using Johnson's human rating requirements, identify any deficiencies, and recommend design modifications to resolve the deficiencies. Ground tests and the space flight test of the X-38[9] deployed from the Space Shuttle are also expected to be major factors in human rating the CRV. If NASA cannot human rate the CRV in this manner, then the Agency prefers to make a decision on CRV production vehicle testing following the X-38 space flight test.

Project Management Explanation and Actions

On May 10, 1999, we met with the Project Manager to discuss the lack of planning for testing the operational CRV and a milestone date for a decision on whether to conduct the testing. The Project Manager responded that an operational CRV test was still an option. He had discussed the issue in a March 1998 Project review, which included CRV operational test considerations and options. He also emphasized the importance of proceeding with the assessment of the outcome of the X-38 space flight test and with conducting ground tests. The Project Manager explained that neither the ISS Program Office nor the X-38/CRV Project Office had planned for or scheduled operational CRV testing because it was not a baseline requirement, sufficient basis existed that human rating might be achieved by an X-38 space flight test, and time was still available to address the issue. The Project Manager also stated that a decision regarding CRV operational flight-testing would be best made after the X-38 space flight test.

On May 19, 1999, the Project Manager developed a CRV Production Flight Test Design Milestones package. The package addressed space flight testing, reasons to conduct a test of a production vehicle, items that can be tested only by space flight, and items that can be completely tested without space flight. The package also contained a production test decision tree, design milestones, and design gates[10] for a production flight test. The Project Manager submitted the package to Johnson's Director of Engineering and planned to include the provisions in the risk management plan and to put the decision gate milestones in the X-38/CRV project calendar.

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[7]The risk management process for the ISS Program is discussed in NASA Audit Report IG-99-009, "Space Station Contingency Planning for International Partners," March 9, 1999.

[8]Phase 1 includes developing the X-38 design to the capability of satisfying requirements for the operational CRV and demonstrating the contractor's ability to produce a CRV in Phase 2.

[9]The space flight test will involve X-38 Vehicle No. 201.

[10]A "gate" is a term the Assessment Office uses to indicate an action that must be completed before proceeding to the next step (that is, contract award).

In the April 1999 draft of the Phase 2[11] request for proposal, the Project Office included a possible requirement for the contractor to develop and execute a plan to flight test an unmanned CRV that would be docked to the ISS. The test would include deployment, deorbit burn, reentry, and parafoil flight to a designated landing site. However, the ISS Program has not planned for the test. An operational CRV flight test from the ISS would require at least one additional Space Shuttle flight and manifest request. For fiscal year 2002, the marginal cost of an additional Space Shuttle flight is estimated to be about $84 million.[12]

Concerns of Independent Review Groups

Three independent groups have reviewed the X-38/CRV Project and have expressed concerns about human rating the CRV. Further, two of the groups expressed specific concerns about the lack of a flight test of the CRV.

- **NASA Advisory Council/Cost Assessment and Validation Task Force.** The NASA Advisory Council developed an independent assessment of the ISS using a Cost Assessment and Validation Task Force. In April 1998, the task force reported that lack of a plan for a space flight test of a CRV was a major programmatic risk. The report related both to the technical risk of not conducting operational CRV testing and the cost impact if such testing was conducted.

- **Deliberative process information omitted.**

- As of July 1999, the Project Office had not planned for operational flight testing as a result of the Assessment Office determination.

- **Aerospace Safety Advisory Panel.** The NASA Aerospace Safety Advisory Panel (the Advisory Panel)[13] reviews NASA safety studies and operations plans. The Advisory Panel's

[11]Phase 2 involves production of the CRV, specifically, four CRV's, two CRV berthing adapters, and one set of spare parts, based on the design proposed at the Phase 1 critical design review.

[12]Source: ISS Program Operating Plan, 1998 Recommendation for fiscal year 2002.

[13]The Advisory Panel advises the Administrator on the hazards of facilities and proposed operations with respect to safety standards.

1998 Annual Report addressed the X-38/CRV, stating that the current design included at least 15 unproved technologies and that the entire CRV would have to be thoroughly analyzed and tested before the vehicle is fielded as the lifeboat for the ISS. The Advisory Panel also noted that the ISS plan to use *Soyuz*[14] as an interim CRV is complicated by the uncertain delivery schedule for the *Soyuz*, its 6-month on-orbit life, and Russian launcher capability. The Advisory Panel recommended that NASA not allow limited CRV development time to compromise the conduct of a thorough risk assessment and testing program**.** In July 1999, the NASA Administrator concurred with the recommendation and responded that each contractor will be required to develop a CRV certification plan.

Contingency Planning Needed Now

The NASA Administrator has stated that safety is the Agency's highest order and mission. Safety supersedes cost, schedule, and performance. NASA should take immediate action to plan for the contingency of CRV operational testing because of the U.S. commitment to provide crew return capability, the Agency commitment to safety, and the review groups' concerns about the safety risks of not conducting operational testing. The action should include a test plan and schedule, a milestone for a decision on operational testing, and recognition of the testing as a primary ISS Program risk.

Recommendations, Management's Response, and Evaluation of Response

1. The Director, Lyndon B. Johnson Space Center should revise the X-38/CRV Project Plan to provide for the contingency of CRV operational testing including a test plan and schedule and a milestone date for a decision on the testing.

Management's Response. Concur. The ISS Program Manager established a set of production vehicle space test decision milestones with dates for decisions on the testing and directed they be baselined into the ISS Program. Management also stated that (1) it was yet to be determined whether X-38 testing and CRV ground testing would provide complete validation of the CRV design and that (2) the Project Office would explore alternatives to a Space Shuttle-based test of the CRV, including atmospheric testing of the production CRV. The complete text of management's response is in Appendix B.

Evaluation of Management's Response. Management's comments are responsive to the recommendation. Although management did not specifically address a test plan and schedule, we accept management's statements regarding the uncertainty of the mode of CRV testing as justification for not developing a test plan and schedule at this time. However, we expect that management will develop a test plan and schedule after determining the type of CRV testing to be performed. The recommendation is resolved but will remain undispositioned and open for reporting purposes until corrective action is completed.

[14] *Soyuz* is a manned Russian spacecraft that will be used to support crew rotation and crew rescue missions for the ISS until the CRV is operational. However, *Soyuz* can carry only three crew members.

2. The Director, Lyndon B. Johnson Space Center should include CRV operational testing in the ISS Program risk management system as a primary risk, as defined by NPG 7120.5A.

Management's Response. Concur. The ISS Program Manager directed the cognizant program elements to implement the recommendation. The Project Manager will present the CRV operational test contingency to be formalized as a program risk at the October 1999 ISS Program Risk Assessment Board meeting. The complete text of management's response is in Appendix B.

Evaluation of Management's Response. Management's comments are responsive to the recommendation. The planned action to formalize the operational test as an ISS risk assures that the ISS Program will manage the contingency. The recommendation is resolved but will remain undispositioned and open for reporting purposes until the corrective action is completed.

Appendix A. Objectives, Scope, and Methodology

Objectives

Our overall objective was to evaluate effectiveness of X-38/CRV project management. For this report, we assessed project testing and flight testing, including rating the CRV for human flight.

Scope and Methodology

Our audit included visiting the X-38/CRV Project Office at Johnson, attending a Flight Readiness Review at Johnson, and observing a free-flight[15] test at Dryden Flight Research Center. We examined and tested project records and documentation to evaluate whether project management plans and actions were reasonable. We did not assess the reliability of computer-processed data because we did not use computer-processed data to achieve the audit objectives. Specifically, we:

- Reviewed NASA policies and procedures, ISS Program requirements, the Federal Acquisition Regulation, and draft requests for proposal.
- Interviewed Project Office personnel and review group members.
- Examined review group reports on the X-38/CRV Project and the ISS Program.

Management Controls Reviewed

We reviewed management controls related to the X-38/CRV Project. Specifically, we reviewed the controls established in NPG 7120.5A relative to project approval. Those management controls were effective.

Audit Field Work

We performed audit field work for this report from October 1998 through July 1999. We performed the audit work in accordance with generally accepted government auditing standards.

[15]For this test, free-flight means an unpowered glide of an X-38 after being carried and dropped from a B-52 aircraft.

Appendix B. Management's Response

National Aeronautics and
Space Administration
Lyndon B. Johnson Space Center
2101 NASA Road 1
Houston, Texas 77058-3696

Reply to Attn of: BD5

SEP 16 1999

TO: NASA Headquarters
Attn: W/Assistant Inspector General for Auditing

FROM: AA/Director

SUBJECT: Management Response to Draft Report on the Audit of X38/Crew Return Vehicle – Operational Testing, Assignment Number A9900200

We have reviewed the subject report and appreciate the opportunity to provide comments to the findings and recommendations. We acknowledge the efforts of your audit staff to keep Center management informed regarding the audit findings, which allows an opportunity to resolve any issues and to concur with the findings to provide for operational testing. Our planned actions, including milestone dates, are explained in detail in the enclosure.

If you have any questions regarding this response, please contact Ms. Pat Ritterhouse, Audit Liaison Representative, at 281-483-4220.

George W. S. Abbey

George W. S. Abbey

Enclosure

cc:
EA/J. F. Muratore
OA/E. O. Castro
HQ/JM/J. D. Werner
HQ/MX/G. A. Gabourel

Appendix B

Management Response to Draft Report on the Audit of X38/Crew Return Vehicle – Operational Testing, Assignment Number A9900200

Auditor's Findings

"NASA has made no provision for an operational test of the CRV to determine its safety for human space flight. Instead, the Agency plans to human rate the CRV based on a space flight test of the X-38, certification by the CRV production contractor, and ground tests. Although three independent review groups have expressed concerns about human rating the CRV without operational testing, NASA has not planned or provided for CRV operational testing. NASA prefers to make a decision on CRV operational testing following the X-38 space flight test. While NASA plans to conduct an X-38 space flight test and other risk mitigation activities, the criticality of the CRV to the safety of ISS crew members requires immediate contingency planning for CRV operational testing."

Recommendations for Corrective Action

"We recommend that the Director, Lyndon B. Johnson Space Center:

1. Revise the X-38/CRV Project Plan to provide for the contingency of CRV operational testing, including a test plan and schedule, and a milestone date for a decision on the testing.

2. Include CRV operational testing in the ISS Program risk management system as a primary risk, as defined in NPG 7120.5A."

JSC Comments

Concur. The Inspector General (IG) audit team has identified a critical issue regarding the Crew Return Vehicle (CRV), and we concur with the recommendations to improve the posture of the agency for qualifying the CRV. The International Space Station (ISS) Program Manager directed program elements to implement both of the audit recommendations. Actions have already been taken to implement recommendation 1. Actions to include CRV operational testing in the ISS Program risk management system as a primary risk will be done at the October 1999 Program Risk Assessment Board.

In addition, the ISS Program Manager directed the X-38/CRV project to explore alternatives to space shuttle based test of the CRV including atmospheric testing of the production CRV.

Enclosure

Appendix B

The critical issue in CRV development has always been the validation testing and certification of the design. It is impossible to certify the space flight entry characteristics of the CRV in the same manner as an aircraft because aircraft certification utilizes test techniques that require hundreds of flights. At a marginal shuttle launch cost of $150M (and equivalent cost for expendable launchers of the same size) an aircraft type approach would exceed the cost of the space station program that the CRV is supposed to support. The CRV probably cannot even utilize the same number of orbital flight tests as used to test the shuttle (four) as this would cost over a half billion dollars and tie up a significant percentage of NASA's human launch capability.

The CRV is a human-rated vehicle; however, and thus requires an extensive and comprehensive flight test program. From the start, the X-38/CRV project has used the concept of prototype vehicles that test specific elements of the design. These prototypes have been constructed to test the vehicle design either inflight or on the ground at the same dynamic pressures, altitudes, loads, temperatures and vibration as the operational space flight use. These prototypes operate in a build-up fashion, operating at increasing speeds and altitudes, culminating in a full space test of the X-38/CRV design with a space flight entry from the space shuttle. To date the X-38 project has conducted 26 large-scale parafoil tests as well as four flights of the prototype lifting bodies in the earth's atmosphere.

In addition to the space flight prototypes, the X-38/CRV project utilizes a number of aircraft and space-based testbeds. For example, the key element of the navigation system of the X-38/CRV is being tested on the STS-99 shuttle flight. The X-38/CRV electromechanical actuators are being tested on a NASA high performance aircraft and the flight control laws have been validated on a USAF variable stability aircraft. Many of the human factors aspects of the design have been tested in the microgravity environment of NASA's KC-135 microgravity aircraft.

It is important to recognize that the space shuttle was qualified for human flight prior to its first test flight utilizing the same sort of approach. The unpiloted X-38 space test represents a major step towards increasing flight safety by performing a full validation of the vehicle aerodynamics, aerothermodynamics, systems, performance, stability and control using the prototype. This database will add on the previous three space tests of this basic shape conducted in 1966 by the USAF. The previous database and the X-38 space test represent a major improvement over the equivalent database established before the space shuttle's first human flight.

At this point in the project, it is not clear whether the prototype testing of the X-38, combined with ground testing of the CRV, will serve as the complete validation of the CRV design or whether a full space test of the production vehicle will be required. The four tests of the space shuttle established a performance envelope for the remainder of the program. Whether a single X-38 space test can establish an equivalent database for the life of the CRV project depends on several factors including:

1. The flight test plan of the X-38 test vehicle
2. The success of the X-38 space test and the degree to which performance maps to predictions
3. The differences between the X-38 and selected CRV design
4. The degree to which differences can be validated by ground or other test
5. The final human rating plan for the production CRV

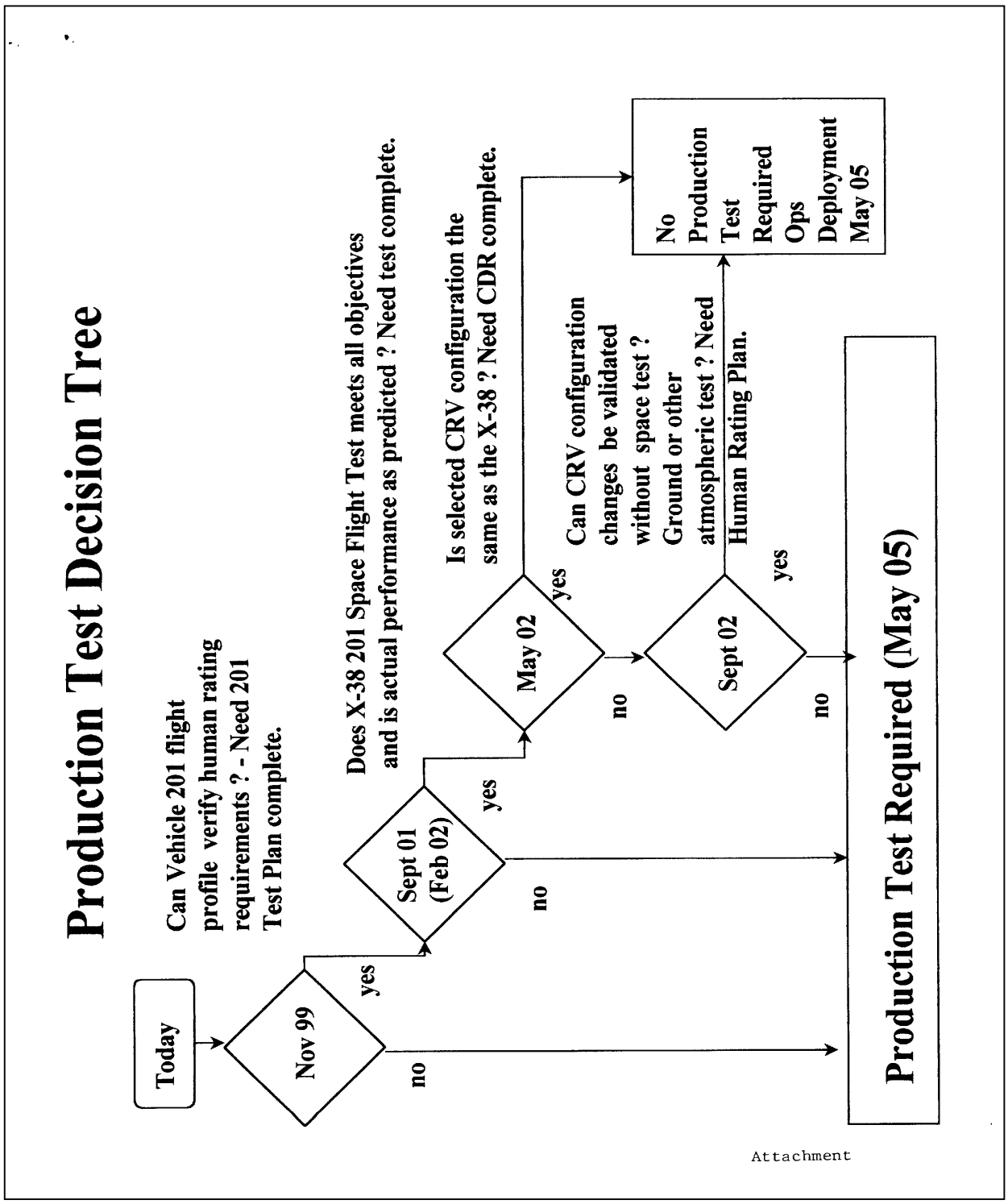
The X-38/CRV project has established a set of decision milestones to determine if a full space test of the production vehicle will be required. These milestones include:

1. November 1999 – Can the X-38 space flight test plan (vehicle 201) include all necessary CRV objectives?
2. February 2001 – Did the X-38 space test meet all objectives? Was performance as preflight predicted?
3. May 2002 – Is the selected CRVC configuration the same as X-38 space test?
4. September 2002 – Can differences between X-38 and CRV be validated by other means such as ground or atmospheric test? Does the final Human Rating Plan require a production test?

The decision flow for these milestones is shown on the attached figure. These milestones were baselined with the International Space Station (ISS) program at the Space Station Integration Control Board (SSICB) held on August 31, 1999, and chaired by the ISS Program Manager. At each of these milestones, new information will be available to determine if a production test is required. The ISS Program Manager directed all ISS program elements, including the X-38/CRV Project Office, to insure that a full up production test of the CRV is not precluded until the final decision milestones have been met. The final decision milestone in September 2002 allows sufficient time to plan for a test of the first production CRV as soon as it is available in May 2005. The recent budget decisions regarding the CRV, received after the Inspector General had published these findings, has delayed the CRV on-orbit date by a year, significantly increasing the time to make such a decision.

We believe these actions fully implement the audit recommendations.

Appendix B


Production Test Decision Tree
Today
Nov 99
Can Vehicle 201 flight profile verify human rating requirements ? - Need 201 Test Plan complete.
yes
no
Sept 01 (Feb 02)
Does X-38 201 Space Flight Test meets all objectives and is actual performance as predicted ? Need test complete.
yes
no
May 02
Is selected CRV configuration the same as the X-38 ? Need CDR complete.
yes
no
Sept 02
Can CRV configuration changes be validated without space test ? Ground or other atmospheric test ? Need Human Rating Plan.
yes
no
No Production Test Required Ops Deployment May 05
Production Test Required (May 05)
Attachment

Appendix C. Report Distribution

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National Aeronautics and Space Administration (NASA) Headquarters

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Branch Chief, Science and Space Programs Branch, Energy and Science Division, Office of Management and Budget
Associate Director, National Security and International Affairs Division, Defense Acquisitions Issues, General Accounting Office
Professional Assistant, Senate Subcommittee on Science, Technology, and Space

Appendix C

Chairman and Ranking Minority Member - Congressional Committees and Subcommittees

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Senate Subcommittee on VA, HUD, and Independent Agencies
Senate Committee on Commerce, Science and Transportation
Senate Subcommittee on Science, Technology and Space
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House Committee on Appropriations
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House Committee on Government Reform and Oversight
House Subcommittee on National Security, Veterans Affairs, and International Relations
House Committee on Science
House Subcommittee on Space and Aeronautics, Committee on Science

Congressional Member

Honorable Pete Sessions, U.S. House of Representatives

Major Contributors to this Report

Dennis E. Coldren, Program Director, Human Exploration and Development of Space Audits

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Nancy C. Cipolla, Report Process Manager