W September 10, 1999

TO: A/Administrator

FROM: W/ Inspector General

SUBJECT: Assessment of the Triana Mission, G-99-013, Final Report

The Office of Inspector General has reviewed the Triana mission. Based on our review, we believe NASA should reassess (and modify if necessary) its current approach to the mission.

The Triana project intends to send a spacecraft to L1 (a location one million miles from Earth where the gravity of the Earth and Sun effectively cancel out each other) before the end of the year 2000. The spacecraft will gather Earth and space science data from this unique vantage point and transmit color pictures of the Earth for distribution on the Internet.

In the context of NASA's constrained budget and the widespread availability of satellite pictures of the Earth, we are concerned about the cost and changing goals of the Triana mission. A relatively simple and inexpensive mission focused primarily (though not exclusively) on inspiration and education has evolved into a more complex mission focused primarily on science. The added scientific capabilities will increase the amount of data gathered by the mission, but they will also increase the mission's total cost. In addition, due to the mission's circumscribed peer review process,[1] we are concerned that Triana's added science may not represent the best expenditure of NASA's limited science funding (see Sections II, III, and IV of the report).

We are also concerned that the Triana spacecraft, originally conceived as a cooperative effort between university students, industry, and government, is essentially being built, launched, and operated by NASA. Although NASA's major role in developing and launching the spacecraft helped to keep the mission within its budget, the costs of the project's civil servant salaries and overhead, government furnished equipment, and launch on the Space Shuttle must still be borne by the taxpayer (see Section II).[2] NASA's major role in developing and

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[1] NASA diligently peer reviewed the science added to the Triana mission. However, since many of the key mission parameters were decided beforehand, and the schedule for soliciting and reviewing proposals was compressed, the number and variety of submitted concepts was limited. Unlike other <u>science-focused</u> missions from NASA's Office of Earth Science, the basic concept of the Triana mission was not peer reviewed.

[2] The Agency is moving towards a full-cost accounting system that will include many of these costs in the budget of individual projects and programs. The Agency does not plan to include the costs of Shuttle launches in its full-cost estimates for projects using the Shuttle, but in a previous OIG report "Audit of NASA's Full-Cost

launching the spacecraft also does not further the goals of the National Space Policy of 1996 and the Commercial Space Act of 1998, which direct NASA to acquire spacecraft and launch vehicles from the private sector whenever possible (see Sections IV and V and Appendix B).[3]

We believe these concerns are of sufficient magnitude that the Agency should reassess its current approach to the Triana mission, and modify that approach if necessary. If NASA decides to modify the mission, the Agency could choose from a variety of approaches (see Section VI). These could include:

- Essentially moving forward with the current design, but launching on a commercial launch vehicle and taking steps to maximize the mission's scientific and educational potential. This would bring the mission into alignment with the goals of the Commercial Space Act and maximize the educational and scientific benefits, but at a relatively high cost. If budget constraints mean that this approach is infeasible, the next two approaches (particularly the final one) present less costly alternatives.
- Re-scoping the mission to reduce its cost and maximize its educational and inspirational component, perhaps by deleting some of the spacecraft's scientific capabilities and/or changing the spacecraft's orbit. This might reduce the amount of scientific data gathered by the mission, but would make a new inspirational view from space available to the public at a lower cost than the current approach.
- Conducting a "Virtual Triana" mission using data from the numerous spacecraft already transmitting pictures of the Earth. "Virtual Triana" is the least costly option, and the one most likely to meet the program's educational and inspirational goals faster, better, and cheaper, but it would gather no new scientific data.

NASA management did not concur with our recommendation. In Section VII, we summarize their major concerns with the report.[4] We respond to those concerns in Section VIII.

Roberta L. Gross

Enclosure
Assessment of the Triana Mission, Final Report

Initiative Implementation" (Report Number 99-024) we recommended that NASA develop a methodology to do so (see Appendix C).

[3] The Agency has argued that Triana will be a secondary payload using available capacity on a pre-existing Shuttle flight and thus is not at odds with the goals of the Commercial Space Act. However, Triana project documents describe Triana as a primary payload and the spacecraft appears to fit the existing NASA definition of a primary payload.

[4] Management contends that the Triana mission's evolution occurred as a result of considered judgment and that the peer review process used for Triana is appropriate considering Triana's role as a demonstration mission. They also object to our inclusion of shuttle launch costs and education outreach efforts in our estimate of the mission's total cost, and contend that the launch of the Triana spacecraft on the shuttle as a secondary payload does not conflict with the goals of the Commercial Space Act of 1998.

W September 10, 1999

TO: Y/Associate Administrator for Earth Science

FROM: W/Assistant Inspector General for Inspections, Administrative Investigations, and Assessments

SUBJECT: Assessment of the Triana Mission, G-99-013, Final Report

I. BACKGROUND

The Triana mission[5] was announced to the public in March 1998. The concept proposed was to build and launch a small spacecraft that would provide the public with continuous views of the sunlit hemisphere of the Earth via the Internet by the end of the year 2000.[6,7] The spacecraft would be launched into an orbit around the L1 point, a location one million miles from Earth where the gravity of the Earth and Sun effectively cancel each other out. University students, industry, and government would team in the design, development, operations, and data analysis of the mission. Total mission cost, including launch and operations, was not to exceed $50 million.

NASA issued an Announcement of Opportunity (AO-98-OES-2) for Triana on July 10, 1998. Proposals were due to NASA 6 weeks later, on August 24. The Agency received a total of nine proposals, of which three were deemed compliant. All three compliant proposals incorporated the use of a spacecraft provided by Goddard Space Flight Center (Goddard) and a launch on the Space Shuttle.

On October 27, 1998, after a scientific and technical peer review, NASA selected a proposal[8] from the Scripps Institution of Oceanography at the University of California, San Diego (Scripps). The Scripps proposal featured two primary instruments: a radiometer to measure the radiance of the Earth at different wavelengths and the Earth polychromatic imaging camera (EPIC), designed to take color pictures of the Earth. NASA also selected portions of a

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[5] The mission is named after Rodrigo de Triana, the lookout from Christopher Columbus' ship who first sighted the New World

[6] NASA. Earth-viewing Satellite Would Focus on Educational, Scientific Benefits. NASA Press Release 98-46. March 13, 1998.

[7] The White House. Vice President Gore Challenges NASA to Build a New Satellite to Provide Live Images of Earth From Outer Space.

[8] Triana Earth Radiometry and Imaging (TERI). Proposal Triana-0005-0003. 1998.

proposal from Goddard—an ultraviolet capability for the camera and a plasma magnetometer to monitor magnetic fields and the solar wind.[9] To pay for the enhancements, NASA increased the mission budget to $77 million.

NASA reallocated approximately $35 million of fiscal year (FY) 1999 funds from other Earth Science programs to Triana. The Triana team expects that an additional $42 million will be required to finish development and operate the mission through FY 2003.[10] (Extending the mission beyond FY 2003 would require additional funding.) By the end of July 1999, the Triana team had spent or obligated $24.7 million of this funding. Triana is currently scheduled to launch on Shuttle mission STS-107 in late 2000.

II. COST ANALYSIS

A. Cost History

When the Triana mission was announced in March 1998, NASA hoped to keep the project's cost close to $20 million and definitely below $50 million.[11] NASA hoped commercial participation would further reduce required NASA expenditures.[12] Early in the process of defining the Triana mission, however, teams from both NASA's Jet Propulsion Laboratory (JPL) and Langley Research Center's Space Systems Division (Langley) advised the Agency that the mission would cost significantly more than $50 million. JPL's red team review of Goddard's feasibility analysis estimated the mission would cost $96.5 million (not including the cost of launch, outreach, additional science experiments, or a science team).[13] Langley estimated that building the spacecraft alone (i.e., not including program management, reserves, launch, an upper stage, outreach, additional science experiments, a science team, or operations) would cost $52 million.[14] Both estimates included the cost of labor (because they assumed a commercial company would build the spacecraft).

The peer review of the proposals responding to the AO also advised NASA that the mission could exceed the proposed $50 million budget. The peer review's Cost Sub-Panel rated the

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[9] NASA Associate Administrator for Earth Science. Letter to Francisco Valero (Principal Investigator for the Scripps Triana proposal). October 27, 1998.

[10] NASA Office of Earth Sciences. Triana Breakdown. UPN 359. April 29, 1999.

[11] Sawyer, Kathy. The World, Live – Just a Click Away. Washington Post. March 13, 1998. The $20 to $50 million figure was also mentioned in "Triana: Inspiration and Information for the New Millennium," a presentation to the NASA Administrator on June 4, 1998.

[12] As mentioned in Section IV, the Triana Request for Information, April 2 1998, stated that the mission had commercial potential in (1) building, launching and operating the satellite, and (2) developing and marketing products and/or value added services that take advantage of spatial and temporal resolutions of observations.

[13] The JPL red team was asked to provide a cost and feasibility analysis of Goddard's April 1, 1998 proposal for Triana. The results of the analysis are documented in Preliminary Red Team Review Results. Earth On-Line Satellite. Feasibility Analysis (GSFC Triana L1 Mission). May 19-21, 1998.

[14] Space Systems and Concepts Division, Langley Research Center. Triana Cost Assessment. May 28, 1998.

three eligible proposals in terms of (1) the adequacy and depth of detail/realism of the cost data and cost methodology provided, and (2) the risk of exceeding the $50 million cost cap for the development activities plus a minimum of 2 years of science. The Cost Sub-Panel rated the "adequacy/realism" of the cost data from the winning Scripps proposal as "Fair" and the proposal's risk of exceeding the cost cap as "High."[15]

NASA did not maintain the original budget goal of $20 to $50 million. Instead, NASA chose to increase the size and complexity of the Triana spacecraft, primarily to augment its scientific capabilities.[16] The baseline government spacecraft described in the July 1998 AO was 45 percent heavier than the spacecraft described in the project's April 1998 Request for Information (RFI).[17] The Scripps proposal added a new instrument (the radiometer) to the AO baseline, and increased the complexity of the telescope/camera. NASA added elements of a Goddard proposal to the Scripps proposal and increased the mission budget by $27 million, to $77 million. NASA officials told us that the increased funding was intended to support increased scientific capabilities. The mission budget has not increased since it was set at $77 million.[18]

Consistent with NASA policies, the $77 million figure is composed primarily of direct costs that NASA's Earth and Space Science Enterprises will expend on contractor-supplied hardware and support. Many costs of the mission—including launch, civil service labor, the education effort, and hardware provided by the government—are not included in the project's budget (see Section IIB). This has kept the Triana project's budget from increasing further above its original goals, but may, in some cases, have increased the total cost of the mission.

By manifesting Triana on the Shuttle, for example, NASA ensured that launch costs would not be paid out of the Triana budget. However, the cost of flying on the Shuttle is considerable (see Section IIB), as are the costs associated with modifying the Triana spacecraft to fly on the Shuttle.[19,20] Triana's design is based upon the SMEX-Lite spacecraft,

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[15] Triana Cost Sub-Panel. Summary. Document in Triana peer review file.

[16] Some changes were made to improve the spacecraft's reliability and reduce its risk of failure.

[17] Comparison of Triana Request for Information. April 2, 1998, and Announcement of Opportunity: Triana. AO-98-OES-02. July 10, 1998.

[18] NASA officials told us that, depending on the outcome of negotiations with the Italian Space Agency, the price of the Italian Research Interim Stage (IRIS) used to carry the Triana spacecraft on the Space Shuttle may be assigned to the Triana budget. If this occurs, the project would most likely go over budget.

[19] The costs of modifying Triana to fly on the Shuttle are included in NASA's full-cost estimate for the mission.

[20] JPL's red team review of Goddard's Triana feasibility analysis argued these same points in the context of launching the original, smaller spacecraft: "A Taurus XL or Athena-2, with a Star 37 final stage in either case, gives more than 50% launch margin for a direct injection into a lunar flyby phasing orbit. The cost of such an expendable is far less than even the real marginal cost of a Shuttle launch and the advantage is even greater when you consider the additional costs of adding a large solid motor to the spacecraft, making the spacecraft with its kick motor safe for the Shuttle, and designing and building the payload bay hardware for deploying the spacecraft and motor."

which was intended to fly on ELVs.[21] Compared to ELVs, the Shuttle has numerous additional safety requirements,[22] a different launch environment—launch on the Shuttle will expose Triana to some forces greater than the SMEX-Lite was designed to handle[23]—and entirely different requirements for support hardware. Launching Triana on the Shuttle has forced the project to develop a new upper stage system (the Goddard Upper Stage),[24,25] add a 16-pound Safety Inhibit Unit, and use the Italian Research Interim Stage (IRIS) to connect the spacecraft to the Space Shuttle.[26]

In summary, three review panels warned of potential cost overruns. Nevertheless, NASA increased the mission's scientific requirements and budget. The budget for the Triana mission has remained steady since selection of the science proposals, but many elements of the mission are not included in the budget, and moving those elements out of the budget may have increased the total cost of the mission.

B. Estimated Total Cost of the Triana Mission

As part of our review, we developed an estimate of the Triana mission's total cost, including civil service labor, overhead, launch, operations, and utilization. We developed this estimate because many of the costs of the mission are not included in the project's $77 million budget.

1. *Full-cost accounting estimate*

NASA currently does not include most costs of civil service personnel and overhead in the budgets of its programs and projects. The Agency is, however, taking steps to implement a system that will account for the cost of these internal resources on a project by project basis. NASA's Full Cost Initiative, begun in 1995, is targeted for full implementation by October 1, 2000.[27] The intent of such full-cost accounting is to provide useful, detailed cost information for internal management and appropriate cost information for external oversight.[28] Because the extensive work being performed on Triana by NASA civil servants at NASA facilities is not reflected in traditional NASA budgeting, we use full-cost accounting to provide "sunshine" on the real costs of the Triana mission.[29]

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[21] System Requirements. Presentation at Triana Single Design Review. Briefing. Code 730. NASA Goddard Space Flight Center. June 7-9, 1999.

[22] These safety requirements are outlined in the following documents: NSTS/ISS 13830C, NSTS 1700.7B, KHB 17000.7B, NSTS, ISS 18798B, and NSTS 14046D.

[23] Mechanical Systems. Presentation at Triana Single Design Review. June 7, 1999.

[24] Mission to L1. Presentation at Triana Single Design Review. June 7-9, 1999.

[25] Triana STS Mission & Upper Stage Overview. Presentation at Triana Single Design Review. June 7-9, 1999.

[26] System Requirements. Presentation at Triana Single Design Review. June 7-9, 1999.

[27]NASA Full Cost Initiative Implementation Guide, February 1999. (It is our understanding that full implementation may be delayed until mid-2001.)

[28] Office of Management and Budget. NASA Fiscal Year 2000 Budget Estimate. February 1, 1999.

[29] Because NASA traditionally has not included costs of civil servant personnel and overhead in its program budgets, the "full-cost" numbers should not be used to compare the current cost of the Triana mission with the cost of other projects not using full-cost accounting, or with previous cost estimates for the Triana mission.

We obtained preliminary estimates of the full cost of the Triana mission from NASA's FY 2000 "full-cost" budget.[30] The first draft of the Program Operating Plan (POP 99-1) submitted by Goddard using full-cost accounting methodology estimates the cost of the portion of the Triana mission under the Earth Science Enterprise to be $91.7 million.[31] This figure includes civil service salaries, benefits, leave, travel costs, and costs associated with conducting work at Goddard. NASA's Space Science Enterprise is also contributing an estimated $2.7 million (full-cost) to the Triana mission to support the spacecraft's space weather monitoring instruments. NASA's current full-cost estimate for the Triana mission is thus $94.4 million.

2. *Use of government-furnished hardware*
The Triana team has contained the direct cost to the mission by using spare components from previous NASA programs. These components include a hydrazine tank from the Cassini program; sun-sensors, omni antennas, and solar array platelets from the Small Explorer (SMEX) program; and a structural casting from the SMEX-Lite program. We could not obtain definitive information about the cost of these spare components during our assessment activities. It can be argued that the components are essentially "free" since they have already been paid for, but it could also be argued that they might have been valuable assets for use in other programs.[32] However, based on discussions with experts both within and outside the Triana mission, we estimated the value of the spare components to be used in the Triana spacecraft to be between $1 million and $5 million.

3. *Use of the Italian Research Interim Stage*
NASA's full-cost estimate for the Triana mission also does not include the cost of the Italian Research Interim Stage (IRIS), which will be used to carry the Triana spacecraft on the Space Shuttle. NASA originally hoped to borrow the IRIS in exchange for the future launch of an Italian satellite. NASA's Associate Administrator for Earth Science indicated that the monetary value of such an exchange might be between $3 and $5 million. However, NASA has not yet been able to reach a satisfactory agreement with the Italian Space Agency on an exchange. If NASA and the Italian Space Agency cannot agree on a barter agreement, NASA will have to pay for use of the IRIS. The Triana project estimated this price would be from $5 to $6 million.

4. *Operations costs for the full 5-year mission*
The Triana mission goal is to conduct operations for 5 years. However, Triana's $75 million budget accounts for only the first 2 years of operations costs. Since officials in the Triana project estimate that operations costs for each of the final 3 years of the mission would be

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[30] As a part of the Full Cost Initiative, NASA is preparing a pilot "full cost" FY 2000 budget (in addition to the Agency's "business as usual" submission).

[31] The full cost budget estimates associated with Triana presented in this report should be considered preliminary. They are Goddard's initial estimate for POP 99-1 and should not be characterized as the Agency position. As the POP 99-1 budget formulation process continues, changes to these estimates can occur, as Triana requirements are balanced against competing funding demands.

[32] Most of the spare parts being used for Triana, with the possible exception of the SMEX-Lite structure, could be used on a wide variety of spacecraft.

similar to those for the second year (an estimated $2.9 million), we estimate the total additional operations costs to be $8.7 million ($2.9 million x 3 years).

5. *Education funding*
NASA's full-cost estimate does not include funding for educational efforts connected with the Triana mission. NASA plans to release a separate NASA Research Announcement (NRA) for Triana education outreach around April 2000. Funding has not yet been allocated for this effort (an unsuccessful attempt was made to fund the Triana NRA during the FY 2000 budget process). Although the amount of funding has not been resolved, officials involved in the Triana education effort expect to request about $4 million per year. Over the full 5-year operational lifetime of the spacecraft, the total cost of this effort would be approximately $20 million.

6. *Shuttle launch cost*
The cost of launching Triana on the Space Shuttle must also be included in the total cost of the Triana mission. NASA does not currently determine the cost of flying its own payloads on the Shuttle, but the costs are nevertheless real. Our office has previously recommended[33] that NASA develop a methodology for determining the costs of using the Space Shuttle (as well as other service-oriented programs) in order to ensure that the full cost of projects that benefit from these programs is consistently recognized and reported. NASA does not concur with this recommendation, but we continue to work with the Agency on this issue (see Appendix C).

A variety of approaches can be used to determine the cost of a Space Shuttle flight. One approach is to divide the cost of the Shuttle program for a given year by the number of flights the Shuttle makes that year. Using this method, NASA's Office of Space Flight estimates the average cost of a Shuttle flight to be $438.7 million for FY2001.[34] Another approach is to estimate the marginal costs of adding a single Shuttle flight to the manifest. Using this method, NASA's Office of Space Flight estimates the marginal cost of a Shuttle mission to be approximately $83.7 million.[35] In its contract with Spacehab, Inc., NASA used a third approach, citing a "cost per flight attributable to payloads" of $165 million.[36]

The portion of a Shuttle flight cost attributable to Triana can be estimated roughly by calculating the fraction of the Shuttle's payload capacity taken by the Triana spacecraft and its associated support hardware.[37] Triana's control mass is estimated to be approximately 9,400

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[33] NASA Office of Inspector General. Final Report on the Audit of NASA's Full-Cost Initiative Implementation. Report Number 99-024. March 31, 1999.

[34] Office of Space Flight. Cost Per Flight. Briefing to Congressional Staff. January 13, 1999.

[35] NASA Office of Space Flight. Marginal Cost FY-02 Flight Added. Space Shuttle Program. POP 98 Recommendation.

[36] Spacehab Phase One Contract NAS9-19250. Modification 34. The pricing issue is discussed further in: Audit of Transportation Costs for Non-NASA Payloads Flown in the Spacehab Module. Audit Report IG-98-028. NASA Office of Inspector General, September 8, 1998. http://www.hq.nasa.gov/office/oig/hq/ig-98-028.pdf

[37] NASA used a similar approach during the 1980s to calculate the price charged to commercial payloads on Space Shuttle flights. See International Reference Guide to Space Launch Systems. Steven Isakowitz, AIAA. 1991.

pounds,[38] which is a little more than one fifth of the Space Shuttle Columbia's payload capacity of approximately 45,800 lbs.[39] Therefore, depending on the method used to determine the cost of a Shuttle flight, we can estimate the cost of Triana's portion of the Shuttle flight to range from approximately $17 million (1/5 of $83.7 million) to approximately $87 million (1/5 of $438.7 million).

Launch on the Space Shuttle may result in additional unbudgeted costs to the Triana mission. The Triana team is striving to prepare the spacecraft for launch on the Shuttle in September 2000. Should this launch date slip, additional expenditures would be required to store the spacecraft and maintain the readiness of the Triana team. However, the Triana project has no budget for such expenditures. Since the Space Shuttle program office has informed Goddard that the Shuttle flight on which Triana is scheduled to launch (STS-107) is manifested to launch no earlier than December 2000,[40] it appears likely that additional funding will be required.

7. Estimated total cost of Triana mission

Excluding the potential costs involved with a delayed launch, we estimate the total cost for the Triana mission (as currently planned) to be approximately $144 to $220 million. Table 1 details our cost estimate.

Table 1. Estimated Total Cost of Triana Mission

Cost Element	Approximate Cost
Full-Cost Estimate for Earth Science	$91.7 million
Full-Cost Estimate for Space Science	$ 2.7 million
Government-Furnished Hardware	$ 1 to 5 million
IRIS	$ 3 to 6 million
Operations for FY 2002-FY 2004	$ 8.7 million
Approximate Total (not including launch or education)	**$107 to 114 million**
Education NRA	$20 million
Shuttle Launch Cost	$17 to 87 million
Approximate Total (including launch and education)	**$144 to 221 million**

III. PROCUREMENT AND PEER REVIEW

NASA has described the Triana mission as the product of a rigorous peer review process.[41,42] However, only the science to be conducted on the mission was peer reviewed. Neither

[38] Triana Mass Property Status and Coordinate Definition. Memorandum. June 21, 1999.

[39] NASA. Space Shuttle Primary Description and Requirements Baseline. NSTS 07700 Volume XIV Revision K. 1993.

[40] MA/Space Shuttle Program Weekly Activity Report, June 17, 1999.

[41] Goldin, Daniel. Letter to the Honorable Jerry Lewis. November 13, 1998.

internal (e.g., the NASA education community) nor external advisory groups (e.g., the NASA Advisory Council or the National Academies) reviewed whether a spacecraft beaming back pictures of the Earth on the Internet was the most effective way to educate and inspire the public, or whether L1 was the most appropriate location from which to conduct Earth science investigations.

In contrast, the basic concepts of the Enterprise's other science-focused[43] missions are peer reviewed. Larger, long-term missions are typically subject to a conceptual peer review, often with the advice of the National Academy of Sciences and/or the NASA Advisory Council. Smaller exploratory missions are not subject to this type of high-level review, but are the product of a broad solicitation process that culminates with a peer review of the entire mission concept.[44]

By the time NASA developed an AO for the science to be conducted on Triana, most of the mission parameters—with the exception of the science content—had already been decided. The AO specified that the Triana spacecraft would be located at L1, should cost no more than $50 million, and must include a color camera that could image the Earth in near real-time. Additional constraints were that Triana be launched to L1 by the end of calendar year 2000 and provide images of the Earth over the Internet early in the new millennium. The AO also stated that NASA would launch Triana from the Space Shuttle at no cost. (Proposals could incorporate use of an ELV only if the vehicle was provided at no cost to NASA.) A government baseline design, using a SMEX-Lite spacecraft built by Goddard, was described in the AO, but proposers were allowed to use a different design.

NASA released the AO for the Triana mission on July 10, 1998. Complete proposals were due 45 days later, on August 24. Forty-five days is the minimum response time allowed by Federal Acquisition Regulations for any NASA AO,[45] and is an extremely short response period for an AO of this size and complexity.[46] NASA's compressed schedule for the AO process (and later the development and construction of the spacecraft) was imposed to attempt to meet the goal of providing views of the Earth by the end of the year 2000.

The complexity of the Triana AO was exacerbated by uncertainty about the fate of the Solar and Heliospheric Observatory (SOHO). Shortly after the Triana AO was issued, NASA's Office of Space Science encouraged scientists to propose re-flying SOHO instruments on

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[42] Goldin, Daniel. Letter to the Honorable George Brown. May 19, 1999.

[43] As shown in Section IV, NASA has considered Triana's primary goal to be science since July 1998.

[44] The Earth Science Enterprise's operational weather satellites and New Millennium missions do not undergo conceptual level peer reviews, but they are not science missions. (The New Millennium missions are aimed at accelerating the development of new, space-applicable technologies).

[45] National Aeronautics and Space Administration supplement to the Federal Acquisition Regulation. Version 97.0, effective August 31, 1997. Section 1872.702

[46] For comparison, the Earth System Science Pathfinder (ESSP) project—the Earth Science Enterprise's "faster, better, cheaper" project—utilizes a two-step AO process that gives Principal Investigators (PIs) 6 weeks to prepare a brief initial proposal and, after an initial science peer review, an additional 8 to 12 weeks to prepare a full proposal.

Triana.[47] However, NASA began to recover SOHO during the Triana AO period, and interest in re-flying SOHO instruments on Triana diminished.

The short response period and the AO's complexity appear to have limited the response to the AO. One group interested in proposing, the California Triana Alliance (a partnership which included the University of California, Allied Signal Corporation, Science Applications International Corporation, and others),[48] stated:

> The AO's limited science definition and prioritization (in both earth and space science areas), the confusion with the accommodation of SOHO instruments, the complexity of incorporating the SMEX-Lite baseline, the enormity of budget details…and the unusually compressed proposal schedule have forced us to abandon our efforts to submit a proposal.

NASA received nine proposals in response to the Triana AO. Of the nine, only three were deemed compliant with all mission requirements. The others were ruled non-compliant because they did not encompass the entire mission but rather were for individual mission elements (e.g., scientific instruments and data distribution architectures). The Triana peer review focused on the three proposals deemed compliant with the AO. These proposals were led by PIs from Scripps, Goddard, and the University of Wisconsin, Madison.

Our review of the process indicates that NASA conducted a fair and thorough peer review of the three proposals in a short time frame. The winning proposal, from Scripps, was announced on October 27, 1998, just 2 months after the closing date for after the responses to the AO.

Table 2 compares Triana AO (AO-98-OES-2) with the most recent AO for the Earth System Science Pathfinder (ESSP) program (SSP AO-98-OES-1). An ESSP project is comparable to Triana in terms of budget (ESSP missions cost $90 to $120 million, including launch) and primary objective (Earth Science). The table highlights the constrained mission, compressed schedule, and limited response to the AO for the Triana mission.

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[47] Triana Opportunity for Addressing SOHO Scientific Objectives. July 20, 1998.

[48] Letter to Triana Executive Secretary from California Triana Alliance Program Manager. August 20, 1998.

Table 2. Comparison of Triana AO-98-OES-2 and ESSP AO-98-OES-1

	Triana (AO-98-OES-2)	Earth System Science Pathfinder (AO-98-OES-1)
AO response period	45 days total for detailed proposal	45 days for initial proposal 70 additional days for detailed proposal
Number of compliant proposals received in response to AO	3	22
Orbit defined in AO?	Yes	No
Free launch on Shuttle offered?	Yes	No
"Government baseline" spacecraft detailed in AO?	Yes	No
Amount of time allowed between selection and launch	Approximately 24 months	36 and 48 months. (36 months being reconsidered as possibly too short)

In summary, the basic concept of the Triana mission—launching a spacecraft to L1 to take pictures of the sunlit Earth to inspire and educate—was not peer reviewed. NASA solicited and peer reviewed proposals for scientific investigations to be conducted on the Triana mission, but many of the key mission parameters were decided beforehand, and the schedule for soliciting and reviewing proposals was compressed.

IV. EVOLUTION OF THE TRIANA MISSION

Since its inception in March 1998, many aspects of the Triana mission have changed.

1. Using a government spacecraft and launch vehicle

Federal policy increasingly supports the use of commercial spacecraft and launch vehicles. The National Space Policy of 1996, for example, states "NASA should acquire spacecraft from the private sector unless, as determined by the NASA Administrator, development requires the unique technical capabilities of a NASA Center."[49] The Commercial Space Act of 1998 states "To the maximum extent practicable, the Federal Government shall plan

[49] White House. National Space Policy Fact Sheet. September 19, 1996.

missions to accommodate the space transportation services capabilities of United States commercial providers."[50]

Early concepts of the Triana mission specified neither use of a NASA spacecraft nor a launch on the Space Shuttle. However, the Agency structured an AO that provided strong incentives to use a NASA-provided launch vehicle. The AO offered a free Shuttle launch, but allowed proposers to incorporate alternative launch vehicles into their proposals if they were offered at no cost to NASA. Every proposal incorporated the free Shuttle launch.

The AO did not offer a free NASA spacecraft. However, it did detail a "government baseline" spacecraft design, using a SMEX-Lite spacecraft built at Goddard, that proposers had the option to incorporate into their proposals in whole or part. The AO stated that proposals did not need to use the government baseline spacecraft, but at least one respondent told us that they believed their proposal would "automatically lose" if it did not use the baseline. The government baseline spacecraft was also attractive to potential proposers because it was based on existing hardware that would be made available to the proposer without charge. All three compliant proposals responding to the AO used the government baseline spacecraft.

2. Adding scientific capability

The AO required only that Triana provide a three-color HDTV-quality picture of the Earth. The Scripps proposal added a radiometer and a more capable telescope/camera. When it selected the Scripps proposal, NASA directed the Scripps team to add ultraviolet imaging capability to the telescope/camera and to add a suite of space weather monitoring instruments to the spacecraft.

The addition of these science instruments and investigations to the Triana mission had a major effect on the Triana spacecraft, significantly increasing its mass, complexity and, in turn, cost. As of mid-June 1999, the radiometer had a mass of 51 pounds, the telescope/camera weighed 132 pounds (75 percent more than it did in the Scripps proposal[51] and 400 percent more than pre-AO estimates)[52], and the space weather monitoring instruments had a mass of 36 pounds.[53] Table 3 illustrates how the mass of Triana's instruments has increased over time.

[50] Public Law 105-303. The Commercial Space Act of 1998.

[51] Triana Earth Radiometry and Imaging (TERI). Proposal Triana-0005-0003. 1998.

[52] Review Guidelines and Assumptions. Preliminary Red Team Review Results. Earth On-Line Satellite. Feasibility Analysis (GSFC Triana L1 Mission). May 19-21, 1998.

[53] Triana Mass Properties. http://triana.gsfc.nasa.gov/home/mass.htm June 14, 1999.

Table 3. Mass of Triana Instruments

	Estimated Mass (pounds) March 1998	Mass (pounds) June 1999
Telescope/Camera	27	132
Radiometer	-	51
Space Weather Instruments	-	36
Total	**27**	**219**

The increased power and communications requirements of Triana's enhanced science instruments have further contributed to increases in spacecraft size. The instruments require 115 watts of power[54] (compared to a pre-AO estimate of 20 watts)[55] which affects the minimum size of the spacecraft's solar arrays and batteries. The scientific data from the instruments makes up the majority of the data being transmitted from the spacecraft,[56] which affects the requirements for the communications system.

The increased scientific capability of the Triana mission has also increased the mission's cost. What was originally supposed to be a mission costing between $20 million and $50 million has evolved into a far more expensive mission (see Section II). Triana's FY 1999 funding was reallocated from a variety of other Earth Science Programs:

- $17.9 million from the Ice, Cloud, and Land Elevation Satellite,
- $7.8 million from future Earth Science System Pathfinder missions,
- $5.9 million from Earth Observing System follow-on spacecraft concept studies and definition, and
- $3.4 million from funds available due to the failure and termination respectively of the Lewis and Clark projects. [57]

Other projects may have to be delayed or scaled back to pay for Triana in the FY 2000 and later budgets.

The increased costs of turning Triana into a science mission might be justified if the science on the mission were the best science that could be funded for the money being spent. However, as discussed in Section III, the conditions under which Triana's science was selected were not optimal for producing a wide selection of high-quality proposals.

3. Changing mission goals

The Triana mission's original goals were not primarily scientific. The White House's initial announcement of the mission focused on the new project's inspirational and educational

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[54] System Requirements. Presentation at Triana Single Design Review. June 7-9, 1999.

[55] Review Guidelines and Assumptions. Preliminary Red Team Review Results. Earth On-Line Satellite. Feasibility Analysis (GSFC Triana L1 Mission). May 19-21, 1998.

[56] Ground Data System Status. Presentation at Triana Single Design Review. June 7-9, 1999.

[57] Goldin, Daniel. Letter to the Honorable Jerry Lewis. November 13, 1998.

impact. NASA’s simultaneous announcement highlighted potential use of the project in “down-to-Earth” applications (such as fire and weather monitoring) as well as potential inspirational, educational and scientific benefits.

NASA’s April 1998 Request for Information (RFI) for the Triana mission stated:

> The prime objective of the mission is to provide a "real time" image of the full sunlit disk of the Earth for educational outreach opportunities. We envision engagement of high school and university students in all phases of the mission, from design through operations and data analysis. Images from the satellite would be available through an Internet World Wide Web site to be maintained and updated by the educational community.

A secondary goal was to use observations provided by Triana for meteorological and environmental monitoring as a complement to existing and planned missions. The Agency stated that it would welcome commercial participation in the mission as a means of reaching this goal at a low cost.[58]

When NASA released the AO for Triana, however, the emphasis of the program had changed. The AO stated:

> The Triana Program is intended to accomplish quality Earth remote sensing investigations from the Sun-Earth L1 point…The Triana program has a secondary goal of inspiring and enabling educational opportunities by providing similar images continuously, that is, frequently-updated, sunlit, full-disk views of the Earth made available over the Internet.

Criteria used to judge the proposals responding to the AO were:

- scientific merit
- total cost to NASA, realism of the cost estimate, and cost risk
- degree of student participation in the proposed effort
- feasibility and innovation of the technical approach
- completeness, soundness, and innovation of the management approach

> The scientific merit and cost will be given the greatest, and approximately equal, weight in the evaluation. Student participation will be given a lower weight than scientific merit and cost. The remaining criteria will be given still lower, and approximately equal, weights.

The use of data from the spacecraft for educational purposes was not given any weight in the evaluation. The AO stated that a separate solicitation for education would be released at a later date.

[58] NASA. Triana Request for Information. April 2, 1998.

NASA's peer review of the proposals followed the guidelines in the AO. The winning Scripps proposal was identified by the peer review as being very strong in Earth science with a very strong Earth science team. However, the review team also noted that the proposal was only linked to one NASA education program, had minimal funding for science education at all levels, and did not address the participation of under-served students. In contrast, the proposal from the University of Wisconsin, which was not selected, was judged to have good definition of, and budgeting for, graduate and undergraduate involvement; an excellent outreach plan after launch; and particularly strong student participation. However, the Wisconsin proposal was judged to have a weaker Earth science program than the winning proposal.

At the time of selection, NASA added science from the Goddard proposal[59] to the Scripps proposal. To support the enhanced science mission, NASA added over $25 million to the program budget. In contrast, NASA has not yet allocated any funding for Triana education efforts. An attempt was made to fund a Triana education NRA for FY 2001 in the FY 2000 budget, but the funding was deleted during the budget process.

4. Technology and commercialization

Early on, the Agency viewed the development of new technologies and commercial participation as possible benefits of the Triana mission: "The Triana mission offers opportunity for validation of technologies of benefit to Earth and Space Science: advanced low-cost, high-performance end-to-end spacecraft architectures, miniature highly autonomous spacecraft, lightweight mirror technology, and advanced charge-coupled device cameras."[60] However, the use of new technologies was not mentioned as a goal in the AO and the current spacecraft design does not appear to incorporate any significantly new technologies.

Similarly, NASA initially hoped private industry would play an important part in the Triana mission. The RFI envisioned commercial potential for the Triana Mission in… "(1) building, launching, and operating the satellite, and (2) developing and marketing products and/or value added services that take advantage of spatial and temporal resolutions of observations."[61] Three respondents to the RFI discussed commercial data purchases, and two of the noncompliant respondents to the AO proposed commercial participation in the system. Although Scripps is currently discussing commercial data purchase arrangements with one of the interested companies, commercial participation to date has been limited to contractor roles.

5. Summary

Table 4 summarizes the changes in the Triana mission over time.[62]

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[59] The peer reviewers rated the Goddard proposal as having some strong Earth and space science elements and a potential for substantial student participation. The proposal was judged to be weak in Earth science education and cost estimation. The proposal's strong Earth and space science elements were selected for incorporation into the mission.

[60] Triana: Inspiration and Information for the New Millennium. Presentation to the NASA Administrator. June 2, 1998.

[61] NASA. Triana Request for Information. April 2, 1998.

[62] Table 3 uses data from the relevant NASA documents, as well as from NASA web pages, interviews with Triana team members and other NASA officials, NASA press releases, and OIG calculations.

Table 4. Triana – Changes Over Time

	Original Concept March, 1998	Request for Information April, 1998	Announcement of Opportunity July, 1998	Proposal Selected October, 1998	Present August, 1999
Budget (using traditional NASA accounting methods)	\$20 - \$50 million	Less than \$50 million (including launch and operations)	\$50 million (not including launch or education NRA)	\$77 million (not including launch or education NRA)	\$77 million (not including launch or education NRA)[63]
Mass	330 pounds	330 pounds	484 pounds (for baseline government approach)	Minimum 550 pounds (estimate based on added instruments)	986 pounds (not including propellant)
Primary Goal	Inspiration, education, applications, and science	Educational outreach	Primary goal is science. Secondary goal of inspiring and enabling educational opportunities.	Science	Science
Spacecraft Bus	Undefined	Small satellite based on proven design	SMEX-Lite offered as baseline government approach	SMEX-Lite heritage spacecraft	SMEX-Lite heritage spacecraft
Instruments	8 inch telescope with 2xHDTV sharpness	8 inch telescope with better than HDTV sharpness	HDTV sharpness camera. Additional instrument proposals welcome within funding and spacecraft resource constraints.	• 12 inch telescope with HDTV camera for visible, IR, and UV • advanced radiometer • space weather monitoring instrument	• 12 inch telescope with HDTV camera for visible and UV • advanced radiometer • space weather monitoring instrument
Camera Colors	3 color	3 color	Minimum 3 color (enhancements ok if within budget)	6 optical bands, 6 infrared bands plus UV	10 bands (UV and visible to near-IR)

(continued)

[63] As shown in Table 1, our calculated total cost of the mission at the present (using full-cost accounting, including the costs of launch, an education NRA, the IRIS, operations costs for the full 5-year mission, and government furnished hardware) is from \$144 to \$221 million.

Table 4. Triana – Changes Over Time (continuation)

	Original Concept March, 1998	Request for Information April, 1998	Announcement of Opportunity July, 1998	Proposal Selected October, 1998	Present August, 1999
Visible Image Distribution	New image every few minutes, available worldwide via TV and internet.	New image every few minutes, with free worldwide access on the Internet.	Images frequently updated, widely disseminated on Internet and perhaps other media.	Minimum 500 images/day (one image every 3 minutes)	1 image per 15 minutes. Funding for Internet dissemination minimal
Student Role	Ground stations to be operated by students. Students involved in design, development, operations, and data analysis.	Engagement of high school and university students in all phases of the mission from design through operations, and data analysis	Student participation at all levels is encouraged and student involvement is "a key evaluation criterion."	Plan to solicit proposals for educational applications in 1999. "Hope and expect participation by students in every phase."	Student participation minimal. No funding for education. Plan to submit RFP for education in 2000.
Launch	Launch by 2000 (launch vehicle not defined)	Secondary payload launched on ELV or Shuttle in 2 years or less	By end of 2000 on Space Shuttle (unless ELV is available at no cost)	December 2000 Shuttle launch	Planning for late 2000 Shuttle launch

In summary, the size, cost, complexity, and purpose of the Triana mission have changed since its inception. A low-cost mission primarily aimed at inspiring and educating students and the public has become a larger, higher-cost science mission with, as yet, minimal educational content. Initial plans for new technologies and student participation have not been realized—the Triana spacecraft uses no significant new technologies and will be built chiefly by NASA, launched by NASA, and operated by NASA contractors.

V. LAUNCH ON THE SHUTTLE

Public Law 105-303, the Commercial Space Act of 1998 (the Act) directs the government to purchase space transportation services from commercial providers to the maximum extent possible. Payloads that can make use of the cargo space on a Space Shuttle mission as a secondary payload are exempted. The Request for Flight Assignment for the Triana Spacecraft,[64] submitted on November 12, 1998, stated that "Triana will be launched to low Earth orbit as a STS secondary payload." At the time this form was submitted, the characterization of the Triana spacecraft as a secondary payload might have been valid. However, as the program has matured, the identification of Triana as a secondary payload

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[64] Request for Flight Assignment (NASA Form 1628) for the Triana Spacecraft. Memorandum to Johnson Space Center. November 12, 1998.

may no longer be accurate, and launch of Triana on the Shuttle may now conflict with the goals of the Act. See Appendix B for a more detailed evaluation.

Triana's launch on the Shuttle also represents lost income to the private sector and lost opportunities for other payloads to fly on the Shuttle. Shuttle launch opportunities for non-space station payloads are currently a very limited resource because three of the nation's four Shuttles will be dedicated to supporting the International Space Station through at least FY 2004. NASA identified four payloads that could fly on STS-107 if Triana were not manifested. These include a Next Generation Space Telescope pathfinder experiment,[65] a collection of space science experiments, a collection of Earth science experiments, and a collection of technology demonstration experiments.[66] Since all of these payloads are significantly smaller than Triana, it is likely that more than one could fly in Triana's place.

VI. ACCOMPLISHING THE TRIANA MISSION

Since announcement of the Triana mission, the project's cost has greatly increased and its goals have changed. Early plans for substantial educational and commercial participation have not been realized, and NASA's role in building and launching the spacecraft does not further the goals of the Commercial Space Act and the National Space Policy of 1996. Based on this assessment, we recommend:

Recommendation 1: NASA should immediately reassess (and revamp if necessary) its current approach to the Triana mission.

The Agency has many options for proceeding with the mission, including those we discuss below. Whatever the decision, it would be in the best interest of cost-effective program management for NASA to act expeditiously. Through the end of July, NASA had spent (or obligated) $24.7 million on the Triana mission.[67] By the end of October 1999, the mission will have spent more than $40 million. As detailed in Section II of this report, total life cycle cost for the Triana mission (as currently planned) is much higher.

The three options below present very different alternatives for the future of the Triana mission. Option 1, "Proceed, With Modifications," would bring the mission into alignment with the goals of the Commercial Space Act and maximize the science return, but at a relatively high cost. Option 2, "Re-Scope and Redesign," might reduce the amount of science on the mission, but would make a new view from space available to the public at a lower cost than the current Triana mission. Option 3, "Virtual Triana," is the least costly option, and the one most likely to meet the program's educational and inspirational goals faster, better, and cheaper, but it would gather no new scientific data.

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[65] NASA's Office of Space Flight is currently working to determine whether the Next Generation Space Telescope experiment can fly on STS-107 in addition to the Spacehab module and Triana.

[66] Goldin, Daniel. Letter to the Honorable John E. Sununu. May, 1999.

[67] Triana Project Termination Assessment. July 13, 1999.

Option 1: Proceed, With Modifications
NASA currently plans to spend a total of about $100 million (plus launch costs, education funding, and operations costs for the extended mission) on the current Triana mission.[68] In order to bring the mission into alignment with the goals of the Commercial Space Act and ensure that the mission produces reasonable scientific and educational benefits, the Agency could take the following steps:

1. Launch from a commercial launch vehicle.
   Launching Triana on a commercial launch vehicle would further the goals of the Commercial Space Act, simplify the design of the Triana mission, and potentially allow more efficient use of Agency resources (by creating a Shuttle launch opportunity that may—depending how you calculate the cost—be worth more than the cost of launching Triana on an ELV).[69]

2. Implement the education effort.
   There is currently no education budget for the Triana mission and students are involved only at a minimal level. For the mission to meet its educational goals, the promised education NRA needs to be planned, funded, and released in advance of the spacecraft's launch.

3. Commit to the full 5-year mission, subject to appropriations
   In the interest of cost-effectiveness, NASA should strive to provide sufficient funding to execute Triana's full 5-year mission. If NASA plans to commit over $150 million to develop, launch, and operate Triana for two years, it would be wasteful not to spend the additional $9 million required to more than double the spacecraft's operational lifetime.

Option 2: Re-scope and Redesign
If NASA wants to launch a spacecraft to inspire and educate the public by transmitting pictures of the Earth on the Internet, but is not willing to spend the approximately $144 to 221 million required to carry out the current mission design,[70] the Agency could re-scope and redesign the mission to accomplish many of its goals at a lower cost. Some potential changes might include: removing some of the science investigations (perhaps incorporating them into other programs), launching the spacecraft on a commercial launch vehicle, using orbits other than L1, and extending the program's schedule.

NASA recently has had success in greatly reducing the budget of planned spacecraft while maintaining most of their capabilities. The Far Ultraviolet Spectroscopic Explorer (FUSE) and the Chandra X-Ray Observatory provide two examples. FUSE was a $300 million Shuttle-launched spacecraft program in 1994 when budget cuts threatened the program. FUSE went through a metamorphosis—the spacecraft was purchased, instead of built in-house, the program management was delegated to Johns Hopkins, and the launch was moved

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[68] Based on our estimates of the mission's total cost in Section IIB.

[69] Launch of the Triana spacecraft to L1 on a Delta 2 would cost approximately $40-50 million (according to a NASA Expendable Launch Services Chart from the NASA Office of Space Flight, June 14, 1999)

[70] Based on our estimates of the mission's total cost in Section IIB.

to a commercial Delta 2 launch vehicle. While the program maintained 70 percent of the mission objectives, the cost for the 3-year mission was reduced to approximately $200 million.[71] Similarly, the Chandra (formerly AXAF) program was restructured in 1992 to cut costs. The original observatory had six mirror pairs and would have been serviced by the Shuttle over a 15-year mission in low-Earth orbit. Chandra was restructured into an observatory with four mirror pairs that will launched into an elliptical high-Earth orbit for a 5-year lifetime, reportedly saving the program about $3 billion, while maintaining most of the program's objectives.[72,73]

One method of reducing the cost of the Triana mission would be to remove some of the science goals that were added to the mission. Removing added instruments and instrument enhancements will reduce the spacecraft's complexity, mass, and cost. Removing a scientific instrument not only reduces system mass, but also decreases spacecraft power requirements, communications requirements, and the overall complexity of the system. Science experiments removed from the mission need not be lost forever—instead they can be proposed into NASA's peer-reviewed science programs, where they can compete against other scientific inquiries for funding.

Another option that might reduce the cost of the mission would be to choose a different orbit. The L1 halo orbit has some unique features, but other orbits also have useful features and might allow NASA to use a less expensive launch vehicle and upper stage. Useful features of the L1 orbit include a stable thermal environment and simple pointing requirements (i.e., spacecraft in L1 are steadily heated from one side and do not have to constantly rotate to see the Earth). From L1, viewers could always see a fully lit almost-full disk of the Earth and would occasionally be able to see the Moon pass across the Earth.

On the other hand, the L1 orbit has some negative features. First, a relatively large upper stage is required to deliver the spacecraft out of Earth orbit to L1. From the remote vantage point of L1, Earth appears only about the size of a quarter held at arms' length, so a relatively large telescope is required to acquire a detailed image, and communication requires relatively powerful transmitters and large receiving antennas. Observers watching the view from L1 will be unable to watch their home town slip from daylight to evening to night, will not see city lights at night, and will at times be unable to see the Arctic or Antarctic regions.[74]

Other orbits will have different advantages and disadvantages. If the Triana spacecraft were launched into an inclined orbit with a 50,000-km altitude, for example, it would be 20 times closer to the Earth than L1, and would see 44.1 percent of the Earth's surface at once, (as opposed to the 49.8 percent visible from L1). In this orbit, as Triana moved across the Earth—and the Earth moved under Triana—it would see the terminator (the line separating day from night), the Earth at night, and both of the Earth's polar regions. From this orbit, a

[71] NASA Public Affairs Office. FUSE Pre-Launch Press Science Briefing. NASA Headquarters. June 8, 1999.

[72] Goldin, Daniel. Speech to the American Astronomical Society. San Antonio, Texas, January 17, 1996,

[73] NASA FY 2000 budget request

[74] Due to the Earth's axial tilt, Triana will be unable to see the Arctic during the northern winter and the Antarctic during the southern winter. When one of the regions is hidden, the other will be visible 24 hours a day.

less powerful telescope would be required, and perhaps a smaller launch vehicle. The question of whether this more rapidly changing, more complete view of the Earth would be as inspirational or educational as the view from L1 is obviously open to debate. The point is that orbits other than L1 could potentially be better locations for a Triana spacecraft. By bringing together educators and engineers NASA may find an orbit that would be as (or more) educational and inspirational as L1, but would cost the Agency less.

If NASA does choose to re-scope the mission, the Agency may also find it useful to postpone the launch date. To meet the planned late 2000 launch date, NASA compressed the process for proposing and selecting mission science (see Section III), and compressed the development time allotted for the spacecraft and its instruments. Allowing the mission to launch at a later date might give the development team the flexibility to use lower-cost approaches and the option to select from a greater variety of launch vehicles.

Option 3 -- Triana: The Virtual Mission

If NASA wants to inspire and educate the public with views of the Earth from space without incurring the cost of launching the Triana mission, NASA could conduct a "Virtual Triana Mission." Virtual Triana would focus on achieving the original goals of the Triana mission without designing, launching, or building a spacecraft. Instead, NASA could dedicate a portion of Triana's proposed funding to developing software and a web site to integrate the vast array of satellite pictures of the Earth already publicly available and make these integrated images available for inspirational and educational purposes.

Images of the Earth from numerous satellites are already available on the Internet. These include visible-light images, as well as infrared, radar, and other wavelength imagery from geostationary and low Earth orbiting satellites. These images can be downloaded from government agencies, commercial companies (such as the Weather Channel[75] and Earthwatch[76]), and university and personal web sites. Some web sites already manipulate the images from multiple satellites to create near real-time montages of cloud, surface, and other data. For example, the Space Science and Engineering Center at the University of Wisconsin produces a global montage using satellite data, sea surface temperatures and observed land temperatures.[77] The Unidata program at the University Center for Atmospheric Research combines multiple sources of infrared satellite imagery with topographic data to provide global pictures and animated movies of the Earth.[78] One of the most technically advanced sites is Goddard's own "A Global View From Space" site,[79] which allows the user to see the Earth in a variety of different wavelengths.

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[75] http://www.weather.com

[76] http://www.earthwatch.com

[77] http://www.ssec.wisc.edu/data/comp/latest_cmoll.gif

[78] http://fatty.unidata.ucar.edu/images/MOLLTOPO.GIF

[79] http://motown.gsfc.nasa.gov/global.select/

A "Virtual Triana" approach that integrates satellite data available on the Internet and makes it available for educational and inspirational purposes would have numerous advantages over the current Triana implementation.

- *More frequent observations*
  The current implementation of Triana would show one image of the Earth every 15 minutes. Each GOES weather satellite already transmits an image every 15 minutes, and these images would be complemented by numerous other inputs to the Virtual Triana project.
- *More complete coverage*
  Virtual Triana would show the entire Earth, rather than just one hemisphere. The virtual Triana would also be able to include imagery of the polar regions at all times of the year, and could show the Earth at night.
- *More flexibility and redundancy*
  Virtual Triana would be expandable as future satellites come on-line and, unlike the current implementation, would not be dependent on the successful launch and continued health of a single satellite. Virtual Triana could integrate visible and IR imagery with ground and satellite radar data, ground temperature readings, and many other sources of data for scientific and educational purposes.
- *Increased student participation in design and development*
  It is much easier for students to participate in development of a web site and software than in designing and building a spacecraft.
- *More advanced technology development*
  Virtual Triana would be a challenging software task that would likely be an excellent test-bed for data fusion approaches that may be used for future NASA planetary missions as well as for commercial purposes on Earth.
- *Scalable cost*
  The budget for Virtual Triana could range from less than a few million dollars to upwards of $20 million. Once the site was running, operational costs would be low and additional funding could upgrade hardware or software or add additional capabilities.
- *Compatibility*
  Virtual Triana could work with and leverage work being done on related education initiatives, including the Globe Program[80] and the Digital Earth Project.[81]

The Virtual Triana mission, however, would not have all the capabilities of the currently planned implementation of Triana. The scientific studies that would have used the radiometer, the solar wind instrument, and the Triana EPIC camera would not be accomplished in the virtual mission. However, NASA has developed well-proven approaches

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[80] http://globe.fsl.noaa.gov/ GLOBE is network of students, teachers, and scientists from over 7,000 schools in more than 80 countries GLOBE students make environmental observations at or near their schools and report their data through the Internet. Global images based on GLOBE student data are displayed on the World Wide Web, enabling students and other visitors to visualize the student environmental observations.

[81] http://www.digitalearth.gov/ The Digital Earth Project intends to create a three-dimensional representation of the Earth that incorporates data from multiple sources and can be viewed at a variety of resolutions.

for flying science missions, and the instruments and investigations that would have flown on Triana can be entered into competition with other scientific research for flight on future spacecraft.

VII. SUMMARY OF NASA MANAGEMENT RESPONSE

We received the Office of Earth Science's response (See Appendix A) on September 9, 1999. The Office did not concur with our recommendation and raised four major concerns with the report:

1. They contend that the Triana mission's evolution occurred as a result of "a thoughtful, positive management decision." The science capabilities of the mission were intentionally increased to maximize scientific benefits from the mission and the project's budget was increased to $75 million for this purpose (and has not increased since then).

2. They consider the peer review process used for Triana to be appropriate considering Triana's role as an exploratory mission to demonstrate the value of viewing the Earth from L1.

3. They believe that the launch of the Triana spacecraft on the Shuttle does not conflict with the goals of the Commercial Space Act of 1998. They maintain that Triana is a secondary payload using available capacity on a pre-existing flight. Further, they contend that the approach used to calculate the cost range for Triana's flight on the Shuttle is inaccurate and should not be included in the cost estimates.

4. They raise objections to the options we suggest for potential approaches to rescoping the Triana mission, stating that the changes would be costly or detrimental.

Management also raises a number of more detailed comments on the draft. These comments, and our response to them, are included in Appendix A.

VIII. EVALUATION OF MANAGEMENT RESPONSE

1. We do not disagree with NASA management's argument that Triana's evolution was the product of due deliberation. Our point is that management's decisions raised the cost and changed the primary objectives of the mission.

2. We disagree with the Agency's position that the limited peer review process was appropriate considering Triana's status as an exploratory, demonstration mission. The description of Triana as an exploratory, demonstration mission is a new one, not mentioned in the initial announcements, the RFI, or the AO. The AO stated that proposals would be judged primarily on "scientific merit and cost," not on whether they are useful in demonstrating the value of L1 for remote sensing. If Triana is a science mission, it should be subject to a concept-level peer review, like NASA's other science missions. If Triana

was intended to be a demonstration mission, the Agency should have solicited proposals for conducting a demonstration mission rather than a science mission.[82]

3. Although the Agency argues that Triana is flying as a secondary payload on the Shuttle (and thus is in accord with the goals of the Commercial Space Act of 1998), the project's own documents refer to it as a primary payload and the spacecraft fits the Agency's only published definition of a primary payload.

   In the report, we use the definition of primary payloads contained in the Space Shuttle Primary Description and Requirements Baseline (not a "technical-level integration document"). Management quotes one sentence from this definition to attempt to argue that Triana is not a primary payload because it will use available capacity on a pre-existing flight. This disregards the description of the primary payload that follows, and ignores the Shuttle program's long history of carrying multiple primary payloads (more than 40 percent of previous Shuttle flights have carried multiple primary payloads). We agree with management's suggestion in their detailed comments that NASA should adopt a definition of primary and secondary payloads to ensure compliance with the Act.

   Management expressed concern about the accuracy of the method we used to calculate the cost of Triana's launch on the Shuttle. However, NASA used a similar method to price Shuttle flights for commercial satellite payloads in the 1980s and for Spacehab payloads in the 1990s. We recognize the inherent uncertainty in the method by providing a range of potential costs in our Shuttle launch cost estimate.

4. Our detailed response to Management's comments about the alternative options for conducting the Triana mission is contained in Appendix A.

IX. SUMMARY

The Triana spacecraft, originally conceived as a cooperative effort between university students, industry, and government, is being built largely by NASA and will be launched, and operated by NASA. The Agency's major role in developing and launching the spacecraft does not advance the goals of the National Space Policy of 1996 and the Commercial Space Act of 1998, which direct NASA to acquire spacecraft and launch vehicles from the private sector whenever possible.

A relatively inexpensive mission focused primarily on inspiration and education has evolved into a more complex mission focused primarily on Earth science. The added science capabilities will result in increased scientific payback. However, the enhancements have greatly increased the total cost of the mission and, due to the limited peer review process, we are concerned that they may not represent the best expenditure of NASA's limited science funding.

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[82] See our response to Management's specific comments in Appendix A for further discussion of Triana's peer review.

We recommend that NASA reassess its current approach to the Triana mission and, if necessary, take steps to revamp the mission.

David M. Cushing

4 Enclosures
Appendix A: Management Response
Appendix B: Triana's Launch on the Shuttle
Appendix C: Accounting for Shuttle Costs
Appendix D: Report Distribution

MAJOR CONTRIBUTORS TO THIS REPORT

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Appendix A

Management Response

National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001

Reply to Attn of: Y

SEP 1999

TO: W/Inspector General

FROM: Y/Associate Administrator for Earth Science

SUBJECT: Draft Triana Report (G-99-013)

I do not concur with your draft report "Assessment of the Triana Mission" sent to my office on August 31, 1999. While discussions between our two offices have substantially improved the draft, basic issues remain. The report's recommendation would have us revisit the fundamental design of a project that is far along in its development and is meeting the objectives set for it within its cost and schedule constraints. Before arriving at this recommendation, the draft report makes several points with which my office takes issue. The major ones are:

See Section VIII

Cost Analysis: The draft claims that despite early concerns of "potential cost overruns", the Agency "increased the mission's scientific requirements and budget." This puts a negative cast on a thoughtful, positive management decision—to maximize the scientific return from Triana and establish a commensurate budget. The draft disguises the most pertinent fact: the cost of the Enterprise's implementation of Triana was set at $75 million at mission selection and remains so today. One legitimate cost threat concerns the deployment hardware sought from the Italian Space Agency; the project office and Headquarters are currently working this issue.

See Section VIII

Peer Review: The draft's discussion of peer review is largely devoid of context. Its conclusion that "the basic concept of the Triana mission...was not peer reviewed" ignores Triana's status as an exploratory, demonstration mission. As with other such missions, NASA identified a promising opportunity in the national interest, in this case, Earth remote sensing at L1, and asked the community to respond with their best ideas. It is on the basis of such demonstrations that peer-reviewed concepts emerge for proven avenues of research.

See Section VIII

Use of the Shuttle: The draft persists in characterizing Triana as a primary payload. However, the draft itself reports the first level test of "primary" is that "a primary payload justifies a shuttle mission, either alone or in combination with other payloads." Triana did not add a Shuttle flight; it is using available capacity on a pre-existing flight. The Office of Space Flight considers Triana a secondary payload.

See Comment 1

See Comment 2

See Comment 3

See Comment 4

See Comment 5

The draft inappropriately relies on technical-level integration documentation in making a policy judgment, given that the policy-level criterion points the other way. The draft seeks to establish a cost for Shuttle capacity and assigns a cost range to Triana for full cost accounting based on payload weight. This approach is inaccurate and should not be included in the cost estimates.

Recommendation Options: The report defines three alternate approaches to Triana implementation which are not realistic. In Option 1, moving to a commercial ELV would cost real money (as opposed to the intangible weight-based costs identified in the report). It would also cost dollars and schedule to redesign the spacecraft for use with a different upper stage. Triana's mission lifetime requirement is two years, with a goal of 5 years. The Enterprise will secure operations for years 3-5 if it is achievable and desirable, but it may not require appropriated funds. Options 2 and 3 are the kind of drastic steps a program takes when it has a >15% overrun and is thus subject to a cancellation review. Triana is not in this situation, even if the cost of the Italian deployment hardware were added to the program (though if necessary, we would more likely seek to solve that within the existing resources.) Option 2 throws the science off the mission in conflict with our Enterprise mandate, and is thus inconceivable. Option 3 was considered during the concept phase; such an approach would not have the same science value, and would not allow a view of the Earth's polar regions with the same time resolution. Further, only two of the five geostationary satellites currently viewing the Earth belong to the United States. Arrangements for access to the other three needed to construct a near-global view would have to be negotiated with foreign governments that have their own commercialization interests.

In short, the report does not provide the reader with an adequate view of the Triana project, and its recommendation would saddle a project that is on track with costly or detrimental changes. More detailed comments on the text of the draft are provided in the enclosure. These comments were submitted in response to Draft 1 and remain an issue.

Ghassem R. Asrar

Enclosure

cc:
Y/Mr. Williams
J/Mr. Sutton

See Comment 6

See Comment 7

See Comment 8

See Comment 9

Detailed Code Y Comments to IG on 3rd Draft Report on Triana

Subject: Per our 7/23 discussion, consider changing the title to "Assessment of the Triana Mission and Attendant Agency-wide Issues" (p.1). Issues of Shuttle primary/secondary payload distinctions and full cost are broader than Triana.

I. Background: Top of Pg. 2; the plasma magnetometer suite was not part of the Goddard proposal. Consider: "Simultaneously, the Office of Space Science asked the Office of Earth Science to accommodate a plasma magnetometer to monitor magnetic fields and solar wind, to be funded by the Office of Space Science."

II.B.1 Full-Cost Accounting Estimate: Pg. 4; Elevate footnote 25 to the main text, and underline it. This is an essential point and should be emphasized.

IIB.7. Table 1: Estimated Total Cost of Triana Mission: Pg. 7; The Education NRA cost element should be a footnote to Table 1. The NASA Full Cost Implementation Guide referenced in footnote 6 makes it clear that full cost calculations are designed to put funding at the point of decision-making (see section 2.1). The education initiative is a Code FE activity which is outside the Earth Science Enterprise as well as outside the Triana project. That initiative is about the use of Triana imagery and data, not the development and conduct of the mission. This education initiative is analogous to scientists' use of Triana (or other mission) data, yet that cost is not included, nor should it be.

III. Peer Review and Procurement: Pgs. 8-10; See discussion in body of memo. Replace the first two paragraphs with the following:

"NASA has described the Triana mission as the product of a rigorous peer review process. While NASA did conduct a peer review of the science that would be conducted on the mission in a manner consistent with like missions, this statement must be set in the context of the various peer review practices employed by NASA. The following summarizes these practices and recounts the history of the review process for Triana.

"NASA's Earth Science Enterprise launches three types of missions: systematic measurement missions to obtain long term observation data sets; exploratory missions to experiment with new observing approaches or new Earth science phenomena; and technology demonstration missions to validate advanced observing technologies. Each of these types has a peer review process commensurate with its nature. In general, the first type is subject to a conceptual-level peer review, often with the advice of the National Academy of Sciences and/or the NASA Advisory Council. This level of review establishes the importance of the scientific measurement to be made or the technology to be developed to an on-going program of research (e.g., climate change), and generally occurs prior to mission definition. Subsequently, an open, competitive solicitation is issued, and proposals are subject to peer review. Exploratory missions, which include ESE's Earth System Science Pathfinder (ESSP) missions (e.g., VCL, GRACE) tend not to arise out of this process. Rather, ESE casts a broad net to identify innovative science ideas that will catch those from outside as well as inside the scientific community hierarchy, and can be done on much smaller budgets and shorter time scales with innovative management approaches. In the case of New Millennium Program (NMP) missions, ESE wants to target specific technologies and/or space environments to facilitate the next big leap in science capability. For example, the 2nd NMP solicitation sought ideas for the geostationary orbit environment. In the latter two classes, peer review is conducted at the stage of proposal evaluation.

"After the Vice-President proposed that NASA launch a satellite to L1 to provide a live image of the Earth to the Internet by the end of 2000, the Agency did study the best technical approach to conduct such a mission, and internally reviewed the approach that emerged. NASA did not seek external (e.g., National Academy of Sciences) or internal (NASA Advisory Committee) advice on the relative merits of such a mission.

"Triana is classified as an exploratory mission. Like other exploratory missions (e.g., ESSP), it did not arise out of National Academy of Sciences or related deliberations. Also like other exploratory missions, a broad solicitation asked for small, low cost, innovative science missions where the science measurements or even science disciplines are not specified in the solicitation; only the Enterprise's science themes are referenced. Like the 2nd New Millennium Program solicitation, the Triana AO specified an orbital environment of interest.

"On April 2, 1998, NASA released an open Request for Information soliciting comments on the utility of Triana imagery and ideas for mission implementation. Over 100 responses were received, categorized as system implementation interest, science interest / suggested mods, education interest / ideas, commercial use of data, and other. NASA concluded from these responses that a valuable science mission to L1 could be developed in the given time frame. In May and June of 1998, NASA developed an Announcement of Opportunity (AO) to solicit for proposals 'to accomplish quality Earth remote sensing investigations from the Sun-Earth L1 point…'."

Continue with the rest of the section starting with the paragraph that begins with "By the time NASA developed an AO…"

In the paragraph beginning "NASA released the AO…", delete the last sentence. The Vice President's challenge to NASA was to launch Triana by the end of 2000. On the occasion of the 30th anniversary of Apollo 11, it would be high irony to make this statement; by the same token we would be suggesting that NASA had 'no urgent need' to put a man on the moon and return him safely to the Earth before the end of the decade.

In the concluding paragraph to this section, replace the first sentence with, "In summary, a peer review process consistent with the exploratory class of missions

See Comment 10

See Comment 11

See Comment 12

was conducted. Also consistent with this class of missions, the basic concept of the Triana mission was not peer reviewed prior to release of an AO." Continue with the rest of the paragraph.

IV. Impact of Triana's Evolution:

On the FY99 cost impacts:

- The impact of movement of funds from ICEsat was a six-month delay in launch. This schedule slip has since been recovered by changes in program implementation approaches and launch vehicle
- Future ESSP missions were not "delayed"; the two missions selected under the 2nd ESSP AO are being developed on schedules that did not require the full amount budgeted for ESSP in FY99.
- Similarly, the definition work on EOS follow-on missions performed in 1998 resulted in lesser requirements for FY99 funds.

The paragraph beginning "Other projects may have to be delayed..." should be deleted. In its passback on the FY00 budget last fall, OMB provided additional funds for Triana (though ESE had to iterate with OMB to address other projects they wanted to impact for other reasons). Regarding the shortage of Shuttle opportunities, Code M recent approached the science offices to solicit ideas to use three research flights they want to add to the Shuttle manifest between 2001 and 2003.

V. Launch on the Shuttle: retain the first three sentences, but replace the rest with "NASA does not have a policy-level definition of 'secondary payload'. Missions like Triana are added to existing flights put on the manifest for some other (primary) purpose. NASA should adopt a definition to ensure compliance with the Act. See Appendix B."

VI. Accomplishing the Triana Mission: See discussion on Recommendation Options in the body of the memo.

IX. Summary: This paragraph ignores the project history; at each stage, the Enterprise sought permission inside and outside the Agency to proceed in the manner it deemed best for the national interest.

Appendix B, Part B: The only section retained should be the discussion of the Secondary Payload exception; it is the only one relevant, and the one on which the decision was based. Delete the discussion of technical-level criteria and PIPs; it is the policy-level definition that is relevant.

OIG RESPONSE TO DETAILED COMMENTS

1. We agree with management that Option 1 "Proceed with Modifications" would involve costly changes. These changes, however, would free up space on the Shuttle for other payloads, further the goals of the Commercial Space Act, and ensure a larger scientific and educational payback from the mission. The three options we present serve to illustrate the wide range of potential alternative approaches to the Triana mission. All of these alternatives involve tradeoffs. If budget constraints mean that Option 1 is not viable, Option 2 "Re-scope and Redesign" or (particularly) Option 3 "Virtual Triana," present less costly alternatives.

2. Although the Triana mission has not, to date, exceeded the $77 million budget established for the project in November 1998, the mission's budget has increased more than 50 percent since its initial announcement. The Agency has a strong precedent for modifying the Triana mission—when NASA's Office of Earth Science increased the science requirements and the cost of New Millennium missions, the Agency has chosen to re-scope those missions to reduce their costs and return them to their original goals.

3. Management states that Option 2 "Re-scope and Redesign" throws the science off the mission. (In fact, removing some mission science is only one possible element of Option 2. Option 2 also discusses potential changes to the Triana's launch vehicle, orbit, and launch date.) They state that removing the science would be "inconceivable" since it would conflict with the Enterprise's mandate. However, one of the Earth Science Enterprise's three strategic goals is to "Disseminate information about the Earth system." This includes "increasing public understanding of Earth System Science through education and outreach." A Triana mission without all of the added science could help fulfill these strategic Enterprise goals.

4. Management states that Option 3 "Virtual Triana" would not have the same science value as the current approach to Triana. We agree. The science value will probably be less, but the cost will certainly be lower, the risk will be lower, and the education value may be higher. Their argument that the polar regions of the Earth would not be viewed with the same time resolution by Virtual Triana is true. However, it is not clear that the current approach is superior—a spacecraft at L1 would be unable to see large areas of the Earth's polar regions for months at a time.

5. Management is correct that U.S. geostationary satellites do not cover the entire globe. However, Goddard's own "Global View from Space" web site[83] already combines images from U.S., Japanese, and European geostationary satellites to provide a globe-spanning view. We believe Virtual Triana would present an excellent opportunity for international cooperation in remote sensing.

6. Although this assessment raises broader issues, the report's focus is on the Triana mission.

[83] http://motown.gsfc.nasa.gov/global.select/

7. The assertion that the plasma magnetometer suite was not part of the Goddard proposal does not appear to match the facts. In an October 27, 1998 letter to the Principal Investigator for the Goddard proposal, the Associate Administrator for Earth Sciences stated

   "…we desire to have you participate with the [Scripps] Principal Investigator (PI), upon your mutual agreement, to improve the science return from the selected mission. … Specifically, we seek to add the ultraviolet capability from your proposal to the Earth imaging camera to be provided by the PI *and to add the PLASMA-MAG solar wind instrument package to the mission*." [Emphasis added]

8. As we state in Section II, the report strives to determine the *total* cost of the mission. The education effort for Triana represents part of this cost, regardless from which part of NASA's budget it is drawn.

9. Our concern with the peer review of the Triana mission is that the Earth Science Enterprise decided to transform Triana into a science mission, but did not subject Triana to the same level of peer review as the Enterprise's other science missions. Unlike the Enterprise's other science missions, most of the mission parameters (orbit, primary instrument, etc.) for the Triana mission were never peer reviewed. This decision, along with the compressed proposal solicitation schedule, reduced the number and variety of proposals received. Although the New Millennium missions, which are aimed at demonstrating new technologies, undergo a peer review process similar to the Triana mission, the solicitations for the New Millennium missions make it clear that these missions' primary goal is <u>technology demonstration</u>, not <u>science</u>.

10. We do not argue that NASA management was able to move around funds to mitigate the impact of Triana's budget on the referenced programs. However, the fact remains that $35 million was removed from other Office of Earth Science programs to fund Triana.

11. The Office of Space Flight (Code M) confirmed to us that the shortage of flight opportunities on the Shuttle continues. The three research flights referred to in the response were proposed in an early round of budget negotiations. Only one of those flights remains in the proposed budget, and it may not receive funding.

12. See our response in Section VIII. We agree that the Agency should adopt clear definitions of primary and secondary payloads to ensure compliance with the Commercial Space Act.

APPENDIX B

Triana’s Launch on the Shuttle

TRIANA'S LAUNCH ON THE SHUTTLE

The Triana mission is scheduled to launch on Space Shuttle mission STS-107 in late 2000.[84]

A. Relevant Law

Public Law 105-303, the Commercial Space Act of 1998, states:

> *(a) In General—Except as otherwise provided in this section, the Federal Government shall acquire space transportation services from United States commercial providers whenever such services are required in the course of its activities. To the maximum extent practicable, the Federal Government shall plan missions to accommodate the space transportation services capabilities of United States commercial providers.*
>
> *(b) Exceptions—The Federal Government shall not be required to acquire space transportation services under subsection (a) if, on a case-by-case basis, the Administrator or, in the case of a national security issue, the Secretary of the Air Force, determines that-*
> *(1) a payload requires the unique capabilities of the Space Shuttle;*
> *(2) cost effective space transportation services that meet specific mission requirements would not be reasonably available from United States commercial providers when required;*
> *(3) the use of space transportation services from United States commercial providers poses an unacceptable risk of loss of a unique scientific opportunity;*
> *(4) the use of space transportation services from United States commercial providers is inconsistent with national security objectives;*
> *(5) the use of space transportation services from United States commercial providers is inconsistent with international agreements for international collaborative efforts relating to science and technology;*
> *(6) it is more cost effective to transport a payload in conjunction with a test or demonstration of a space transportation vehicle owned by the Federal Government; or*
> (7) *a payload can make use of the available cargo space on a Space Shuttle mission as a secondary payload, and such payload is consistent with the requirements of research, development, demonstration, scientific, commercial, and educational programs authorized by the Administrator.*

The Commercial Space Act of 1998 went into effect on October 28, 1998 and does not apply to space transportation services and space transportation vehicles

[84] Flight Assignment Working Group. Space Shuttle Program Manifest & Flight Integration Office. Johnson Space Center. Houston, Texas. April 23, 1999

acquired (or owned or contracted for) by the Federal Government before that date. However, the Act repealed 42 U.S.C. 2465d (in effect from November 16, 1990 until October 28, 1998), which contains similar language (with fewer exceptions).[85]

B. Application of Relevant Law to Triana Mission

1. Exception (b)(1): Does Triana require the unique capabilities of the Shuttle?
The Triana spacecraft is based on the SMEX-Lite design, which was intended for launch on a Pegasus launch vehicle. Triana will be the first SMEX-type spacecraft to launch on the Shuttle instead of an ELV.[86] Although it would be possible to design features into Triana that would require a Shuttle launch, such features are not required to execute the Triana mission. Thus, Triana does not require the unique capabilities of the Shuttle

2. Exception (b)(2): Are cost-effective commercial launch services for the mission not reasonably available?
NASA has been able to procure a variety of commercial launch services to send other spacecraft into L1 orbits. For example, the International Sun-Earth Explorer-3 (ISEE-3) was launched to L1 by a Delta rocket in 1978, SOHO was launched to L1 in 1995 by an Atlas 2AS, and the Advanced Composition Explorer (ACE) was launched to L1 in 1997 on a Delta 2. NASA's next scheduled mission to L1, the Genesis mission, will be launched in January 2001 on a Delta 2. Cost-effective commercial launch services to L1 appear to be readily available.

3. Exception (b)(3): Would use of commercial launch services pose an unacceptable risk of loss of a unique scientific opportunity?

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[85] 42 U.S.C. 2465d reads:

(a) In General—Except as otherwise provided in this section, the National Aeronautics and Space Administration shall purchase launch services for its primary payloads from commercial providers whenever such services are required in the course of its activities.

(b) Exceptions—The National Aeronautics and Space Administration shall not be required to purchase launch services as provided in subsection (a) of this section if, on a case by case basis the Administrator of the National Aeronautics and Space Administration determines that –

(1) the payload requires the unique capabilities of the space shuttle;

(2) cost effective commercial launch services to meet specific mission requirements are not reasonably available and would no be available when required;

(3) the use of commercial launch services poses an unacceptable risk of loss of a unique scientific opportunity; or

(4) the payload serves national security or foreign policy purposes.

Upon any such determination, the Administrator shall, within 30 days, notify in writing the Committee on Science, Space, and Technology of the House of Representatives and the Committee on Commerce, Science, and Transportation of the Senate of the determination and its rationale.

[86] Space Shuttle Program Office. Payload Integration Plan for Triana. NSTS 21462. NASA Lyndon B. Johnson Space Center. April, 1999.

Although use of a commercial launch provider might pose a higher risk than a Shuttle launch of not delivering Triana to its orbit, numerous NASA payloads accept the potentially higher risk and are launched on commercial launch vehicles each year. During the second half of 1999, for example, six NASA payloads are scheduled for launch on four different types of commercial launch vehicles.[87] In addition, loss of the Triana spacecraft would not cause the loss of unique scientific opportunity. Unlike a mission to a comet, for example, the opportunity to image the Earth from L1 will continue to be available for future missions whether or not Triana is launched successfully. Use of commercial launch services for Triana would not pose an unacceptable risk of loss of a unique scientific opportunity.

4. Exception (b) (4): Would the use of space transportation services from United States commercial providers for Triana be inconsistent with national security objectives?
The Triana mission is focused on science and education. It has no identified national security applications.

5. Exception (b) (5): Would the use of space transportation services from United States commercial providers be inconsistent with international agreements for international collaborative efforts relating to science and technology?
The only international component of the Triana mission was added in the spring of 1999, when the Triana team decided to use Alenia Aerospazio's IRIS to help connect the Triana spacecraft with the Shuttle payload bay. This, however, is a loan of existing hardware in exchange for future considerations, and not a "collaborative effort relating to science and technology." The launch of Triana is not relevant to any international collaborative efforts relating to science and technology.

6. Exception (b)(6): Would it be more cost effective to transport Triana in conjunction with a test or demonstration of a space transportation vehicle owned by the Federal Government?
The Shuttle is no longer in the development or demonstration phase, so this exception cannot apply.

7. Exception (b)(7): Could Triana make use of the available cargo space on a Space Shuttle mission as a secondary payload?
The Payload Integration Plan for Triana—the primary agreement between the Triana mission and the Space Shuttle Program—states that Triana "will fly on a shared flight as a primary payload."[88] The Triana spacecraft also appears to fit NASA's definition of a primary payload. NASA defines primary payloads in the Space Shuttle Primary Description and Requirements Baseline:[89]

> Primary: A primary payload justifies a Shuttle mission, either alone or in combination with other payloads, and meets the criteria of the Shuttle use policy

[87] NASA. Integrated Launch Manifest. April 26, 1999.

[88] Space Shuttle Program Office. Payload Integration Plan for Triana. NSTS 21462. NASA Lyndon B. Johnson Space Center. June 14, 1999.

[89] NASA. Space Shuttle Primary Description and Requirements Baseline. NSTS 07700 Volume XIV Revision K Change 1. 1993.

set forth in NMI 8610.12B, Policy for Obtaining Office of Space Flight Provided/Arranged Space Transportation Service for NASA and NASA-Related Payloads, as determined by the NASA Flight Assignment Board and approved by the NASA Administrator. A primary payload typically defines the critical path of the integration process, including KSC processing, flight design and mission operations preparation, and post-flight processing and data reduction. A primary payload normally has one or more of the following characteristics:

- Control weight of 8000 pounds or more
- Payload telemetry downlink requirement greater than 16 kbps
- SMCH requirement for 2 or more sections
- Daily launch window requirement including night launch and/or landing
- Requires deploy/retrieve operations on the same mission
- Requires retrieval and rendezvous operations such as ground up (passive) or control box (active) rendezvous
- Requires 4 or more days of microgravity operations
- Requires 4 or more days of operations at specified attitude(s)
- Requires extended solar or deep space observation periods of 6 or more continuous hours
- Requires dual shift operations
- Requires module vertical access kit
- Requires sensitive or highly sensitive payload bay cleanliness

Triana has at least three of these characteristics: Triana's control weight is more than 9,000 pounds,[90] Triana uses three standard mixed cargo harness (SMCH) sections,[91] and Triana will constrain the Shuttle to one 10-minute launch window per day.[92] Although the requirements have not yet been finalized, Triana may also require sensitive payload bay cleanliness[93] and its telemetry downlink requirements may exceed 16 kpbs (as of June 9, 1999, Triana's telemetry requirement was described as "require 16 kbps, highly desire 64 kbps).[94] We believe it noteworthy that the only other spacecraft to use the Italian IRIS support structure—the LAGEOS spacecraft (which was slightly smaller than Triana)—was also classified as a primary payload.[95]

Some NASA officials have argued that the above definition of a primary payload is a "technical definition," which is separate from the "policy definition." However, we were unable to locate any "policy definition" of a primary payload. NASA also has argued that Triana cannot be a primary payload because the Shuttle mission it is assigned to already has a

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[90] MA/Space Shuttle Program Weekly Activity Report. June 17, 1999.

[91] Space Shuttle Program Office. Payload Integration Plan for Triana. NSTS 21462. NASA Lyndon B. Johnson Space Center. April, 1999.

[92] System Requirements. Presentation at Triana Single Design Review. June 7-9, 1999.

[93] Triana Contamination Engineering. Presentation at Triana Single Design Review. June 7-9, 1999.

[94] STS Mission Operations and Integration. Presentation at Triana Single Design Review. June 7-9, 1999.

[95] JSC-MT3/Manifest & Flight Information. Composite Schedule History. July 10, 1999.

primary payload (a Spacehab double module being used for life and microgravity science research). However, Shuttle flights frequently carry multiple primary payloads. A review of past Shuttle missions shows that 40 missions (more than forty percent of all Shuttle flights) carried two or more primary payloads.[96]

Since the Payload Integration Plan between the Triana project and the Shuttle program identifies the Triana spacecraft as a primary payload and the Triana spacecraft fits NASA's only published definition of a primary payload, we believe that the identification of Triana as a primary payload is correct. The exception does not apply.

In summary, Triana is subject to the provisions of P.L. 105-303, the Commercial Space Act of 1998. Launch of Triana on the Shuttle may conflict with the goals of this law.

[96] JSC-MT3/Manifest & Flight Information. Composite Schedule History. July 10, 1999.

APPENDIX C

Accounting for Shuttle Costs

ACCOUNTING FOR SHUTTLE COSTS

On March 31, 1999, the NASA OIG issued the Final Report on the Audit of NASA's Full-Cost Initiative Implementation (Report Number 99-024). The audit concluded that NASA was making satisfactory progress in implementing the Full-Cost Initiative although it recognized that success was dependent on fielding the new Integrated Financial Management Project, which was not scheduled to be fully operational until FY 2001. The audit found, however, that NASA was not planning to distribute the costs of the Space Shuttle Program to other programs and projects that benefit from the launch services provided.

The OIG recommended that NASA develop a methodology for distributing the costs of the Space Shuttle Program—as well as other service-oriented programs—to benefiting programs in order to ensure that the full cost of these programs is consistently recognized and reported. (This does not mean that we recommend that NASA charge the costs of the Shuttle to benefiting programs, only that the Agency calculate those costs and make them available for management and oversight purposes.)

NASA management concluded in its response to the report that implementation of this recommendation would not be practical because of the extensive cost distributions that would be required and stated that attempts to further distribute costs at this stage in the implementation of full-costing was premature. NASA reaffirmed its disagreement with the recommendation on May 3, 1999, stating that

> *"…the myriad of permutations inherent in the Space Shuttle Program currently are not amenable to refined, recurring, operational cost distributions within NASA's new accounting system or within NASA's full cost structure…We do not plan to pursue additional methodology or system refinements or additional detailed accounting distributions of Space Shuttle Program (or other program) costs to other programs beyond our current practices.*

We continue to support the need for the allocation of Space Shuttle launch service costs to benefiting program, including Triana, and are elevating the nonconcurrence with the audit recommendation to the Audit Resolution Official within NASA. In our opinion, it is appropriate to include Shuttle launch costs in program cost estimates just as the costs of expendable launch services would be reflected.

APPENDIX D

Report Distribution

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