Flight Dynamics Mission Support and Quality Assurance Process*

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Abstract

This paper summarizes the method of the Computer Sciences Corporation Flight Dynamics Operation (FDO) quality assurance approach to support the National Aeronautics and Space Administration Goddard Space Flight Center Flight Dynamics Support Branch (Code 553). Historically, a strong need has existed for developing systematic quality assurance using methods that account for the unique nature and environment of satellite Flight Dynamics mission support. Over the past few years, FDO has developed and implemented proactive quality assurance processes applied to each of six phases of the Flight Dynamics mission support life cycle: system and operations concept, system requirements and specifications, software development support, operations planning and training, launch support, and on-orbit mission operations. Rather than performing quality assurance as a final step after work is completed, quality assurance has been built in as work progresses in the form of process assurance. Process assurance activities occur throughout the Flight Dynamics mission support life cycle. The FDO Product Assurance Office developed process checklists for prephase process reviews, mission team orientations, in-progress process reviews, and end-of-phase audits. This paper will outline the evolving history of FDO quality assurance approaches, discuss the tailoring of CSC's process assurance cycle procedures, describe some of the quality assurance approaches that have been or are being developed, and present some of the successful results.

1.0 Background

Since 1988, the Computer Sciences Corporation (CSC) Flight Dynamics Operation (FDO) has supported the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) Flight Dynamics Support Branch (Code 553) as part of the CSC System, Engineering and Analysis Support (SEAS) contract. In January 1991, the FDO Product Assurance Office (PAO) performed its first formal audit with the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) mission team members at the end of their system installation and acceptance phase. The audit was based on the SEAS System Development Methodology (SSDM) Standards and Procedures (S&Ps). As a result of this session, the PAO and SAMPEX team members realized that better audit results could have been achieved if the audit had been preceded by a coaching session. Since that first audit session, the goal and method of FDO audits have been redirected to assist mission team members in performing their mission support as the work progresses by identifying quality checkpoints and quality criteria and by reviewing the process rather than checking the end results. Consequently, the PAO entered into process reengineering with the FDO technical and management personnel in order to build quality into the work processes. (The terms *product assurance* and *process assurance* are used interchangeably throughout this paper.) Later in the stage of the FDO's audit coaching or proactive quality assurance (QA) process development, the CSC SEAS process assurance cycle (PAC) procedures became available and were tailored to enhance the FDO process. The SEAS PAC comprises a series of reviews and audits before, during, and after each phase of the life cycle. In fact, the FDO has contributed to the SEAS PAC procedure development by providing FDO experiences and review comments for the draft SEAS PAC procedures. In FDO, the technical staff prefer the in-progress process review (IPPR) over the in-progress process audit (IPPA) by the PAO because it fosters a spirit of cooperative problem solving via process reviews, rather than giving the technical staff the impression that the PAO is checking on them.

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2.0 Introduction

The process assurance activities continue throughout the Flight Dynamics mission support life cycle, which comprises six phases:

- System and Operations Concept
- System Requirements and Specifications
- Software Development Support
- Operations Planning and Training
- Launch Support
- On-Orbit Mission Operations

For convenience, the term life cycle *phase* is used here; however, in reality, a specific process such as requirements and specifications may go well beyond the requirements and specifications phase, which is normally considered complete at system requirements review (SRR). Likewise, all other adjacent phases often overlap, particularly during a rapid prototyping process for which a traditional waterfall model is not suitable. Further studies are required to model PAC procedures for such a prototyping process and also for the anticipated changes to a workstation support environment.

Note that those phases that follow the requirements and specifications phase differ from the traditional system development life cycle phases. This difference shows the unique nature of the FDO mission support life cycle. For example, during the software development support phase, the FDO analysts support software development via walkthroughs and respond to developer questions after the system requirements and specifications documents are delivered. The CSC Software Engineering Operation (SEO) performs development in support of GSFC Code 552, Software Engineering Branch.

Prior to the publication of this paper, no known published works have thoroughly described the QA processes for the entire life cycle of the GSFC Flight Dynamics mission. A great deal of effort has been expended within FDO to develop a set of systematic and proactive QA approaches tailored to the unique nature and environment of Flight Dynamics mission support. First, CSC FDO consolidated the existing QA activities and developed a process where those activities occur before the start of and/or during each mission phase in a proactive manner. The proactive QA activities are skills training, weekly internal mission reviews, document QA plans, dry runs, prephase preparation, mission team meeting (combined with just-in-time training for the upcoming phase), IPPRs, and prelaunch readiness reviews. Next, FDO PAO consulted with experienced staff to develop QA checklists for the six FDO mission support life cycle phases. Checklists are used to guide discussion at the IPPRs and LCPAs. The FDO just-in-time (JIT) training materials for the various FDO mission support life cycle phases and FDO document QA checklists were used for the phase IPPR and end of LCPA checklists.

FDO's strategy for producing quality products and services consists of the previously mentioned consolidated QA activities, techniques of coaching/training, lessons learned and feedback for process improvement, defect causal analysis, identification of quality checkpoints and associated quality criteria, identification of S&Ps and development of appropriate guidelines or S&Ps, and innovation. Each mission team within the FDO is responsible for developing and documenting improvements and continuing good practices based on the lessons learned during day-to-day activities or during the generation of products and services. The vehicle used to deploy this approach is the FDO PAC procedure described in the following sections. The FDO PAC procedure is supplemented by maintaining a project lessons learned database, FDO lessons learned database, DCA database, reports, and electronic files or bulletin boards. Communication is promoted among FDO projects on tools and methodologies that may contribute to improved quality and productivity. Methodology effectiveness is monitored and evaluated for improvement.

3.0 FDO PAC Procedure

The FDO quality goals and PAC procedure are described in this section.

3.1 FDO Quality Goals

The goal of the FDO's quality assurance effort is to maximize the quality of FDO products and services. This occurs by maximizing the quality and consistency of the technical processes used and detecting any problems in processes or quality early in the FDO mission support life cycle phases. Corrective actions are taken as early as possible to ensure that all deliverable FDO products and services are of high quality. Documents and reports produced are quality assured using the FDO Product QA Plan with the baseline quality criteria.

3.2 FDO PAC Procedure

The purpose of the FDO PAC procedure is to ensure that task teams have a consistent understanding of FDO mission support processes, products, and S&Ps before the start of each project and mission support life cycle phase. The PAC also shifts the emphasis of product assurance personnel from the traditional role of product inspector to that of process advisor (i.e., the technical personnel are responsible for ensuring the quality of a product or service.) In addition, use of the PAC helps the technical staff and the PAO identify and improve process-related weaknesses as early as possible in the life cycle. Early identification of items that should be changed is a most effective cost reduction/avoidance method. Finally, the PAC provides a standard, efficient, and repeatable mechanism for encouraging process improvement. The SEAS PAC applied to FDO comprises the following five activities:

- Documentation of approach
- Prephase Process Review (PPR)
- Phase Orientation Meeting (POM)
- In-Progress Process Review (IPPR)
- Life cycle phase audit (LCPA)

Figure 1 depicts the flow of the PAC process in each phase.

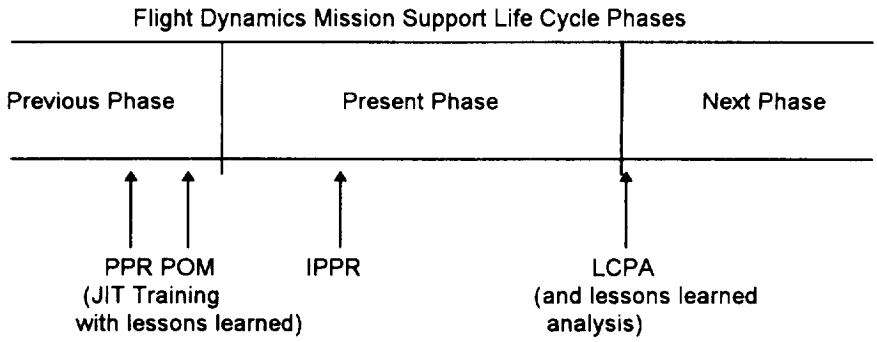

Figure 1. FDO Process Assurance Cycle (PAC) Flow Before/During/After a Phase

The FDO documentation of approach consists of project or task implementation plan, work package plan, and mission support life cycle phase activity plan. The PPR is an informal meeting of the project leader or mission manager with the PAO to review and update the approach (the project- or mission-specific checklist) for the upcoming life cycle phase. The PPR is intended to ensure that the activities, products, and events that are expected to occur during the upcoming life cycle phase are all identified and have corresponding S&Ps. The PPR should take place a few weeks before the start of the life cycle phase. POM is to ensure that all mission or project team

members have a consistent understanding of the S&Ps to be used, the processes that are to be followed, and the products and services to be delivered during the current life cycle phase. The POM is an opportunity for providing JIT training and lessons learned from previous missions for task or mission team members. Depending on the duration of the phases for a given mission or project, it may be appropriate to conduct a POM covering multiple phases. The IPPRs ensure that reviews are performed for task implementation plan, work package plan, and mission support phase activities. The IPPR provides an assessment of the mission or project team members' understanding and conformance to the S&Ps and provides processes that have been designated for use on the task through the mission- or project-specific checklist. The IPPRs occur approximately 15 to 25 percent into the calendar schedule of the task or mission support life cycle phase. This is early enough to correct any weaknesses detected in the process. The IPPR can occur more than once during the phase depending on the results of the first IPPR. At the conclusion of each phase, an LCPA is conducted to ensure that all the requisite activities have occurred and that it is appropriate to proceed to the next life cycle phase. Lessons learned data are collected and analyzed for training and process improvement during this audit.

The FDO adaptation of the PAC procedure uses process checklists for each of the mission support life cycle phases. The FDO Mission Support Process Group and the FDO PAO developed these checklists because the SSDM S&Ps do not address the FDO's mission support phases (Reference 1). The checklist for a given phase provides a list of the SSDM and FDO S&P applicable to the products and services that are developed and/or delivered during that phase. The process checklists may be tailored to meet the particular needs of a project.

4.0 Flight Dynamics Mission Support Life Cycle Phases and Key Processes

Figure 2 depicts the FDO mission support life cycle phases, reviews, and process overlaps. For convenience, numbers are assigned for the life cycle phases in Figure 2a. The activities supported by CSC SEO are identified in the right side of the figure. The reviews (Figure 2b) include system and operations concept review (SOCR), system requirements review (SRR), preliminary design review (PDR), critical design review (CDR), operations readiness review (ORR), and division operations readiness review (DORR). The processes of adjacent life cycle phases actually overlap as shown in Figure 2c. This figure also shows the relative effort of a mission team over time, but process assurance effort is about the same level throughout the life cycle.

Key activities dominate all others for a given life cycle phase. The associated numbers help map activities between the GSFC Flight Dynamics mission life cycle phases and the CSC FDO life cycle phases. The key processes characterizing each phase are summarized as follows:

- ***System and Operations Concept Process (1)***
  - Investigate existing systems to fulfill anticipated mission support requirements using trade-off studies. If no existing system satisfies the requirements, a new system must be developed.
- ***Requirements and Specifications Process (2)***
  - Review and expand the high-level requirements in the detailed mission requirements (DMR) documents; identify items related to orbit and attitude. This process will result in additional refinements and further detailing of the Flight Dynamics support requirements.
  - Create a detailed Flight Dynamics support requirements table and clearly establish traceability of requirements. Continue to maintain the table as a quick reference to critical Flight Dynamics mission support requirements.
- ***Software Development Support Process (3,4,5)***
  - Respond to questions from the software development team. Specifications modifications may be needed as a consequence of the questions.

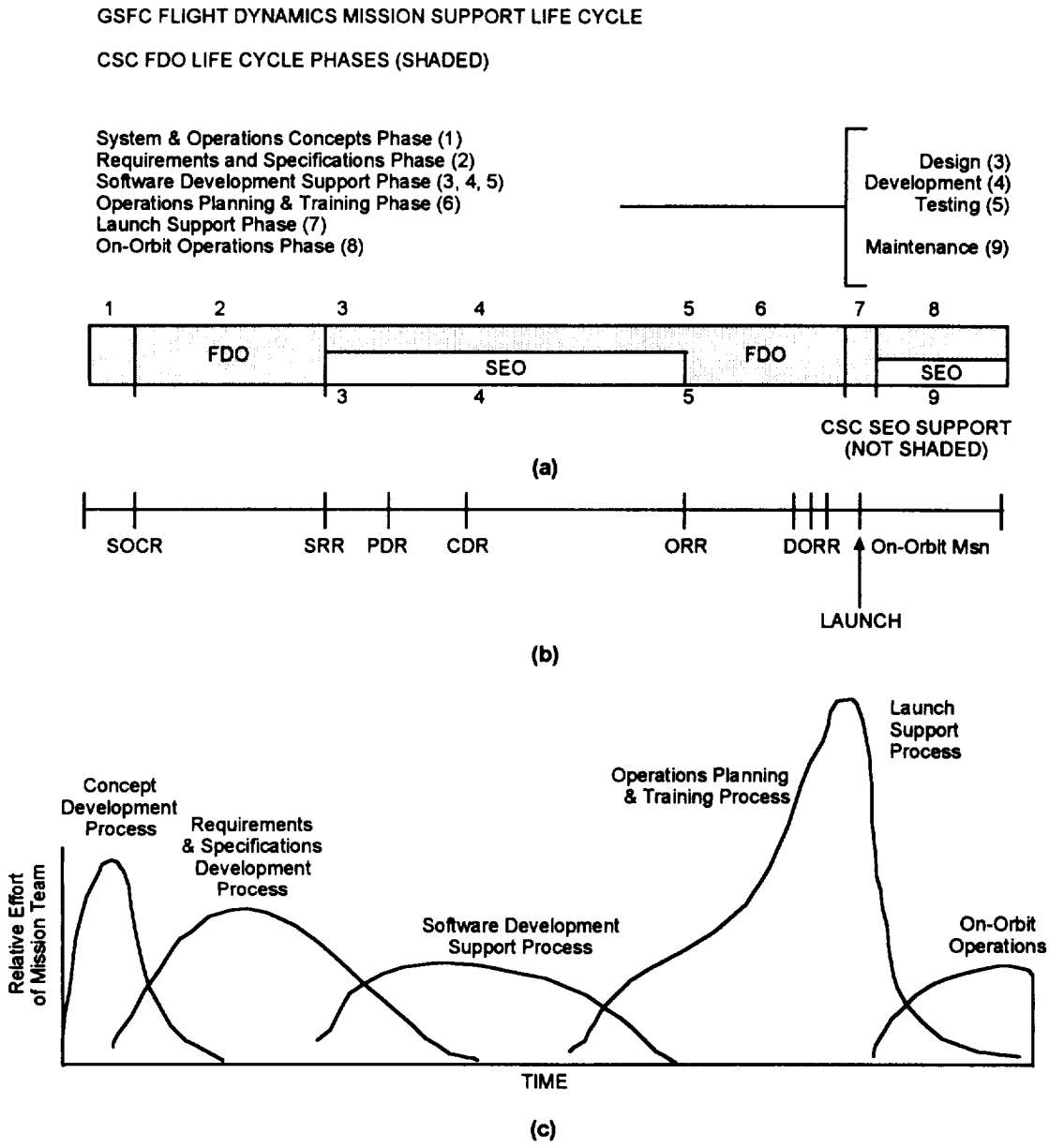

Figure 2. GSFC Flight Dynamics support life cycle consisting of CSC FDO- (and SEO-) supported life cycle phases (a), reviews after each phase (b), and process overlaps (c)

- ***Operations Planning and Training Process (6)***
  - Develop mission support procedures. These procedures are standardized sets of ordered activities that may include software execution and other functions such as requesting, transmitting and archiving data, and logging.
  - Develop mission support timeline and operational scenarios (for example, scenarios for orbit acquisition, attitude acquisition, sun sensor calibration, and spacecraft ascent maneuvers). Each scenario consists of a collection of standardized procedures designed to satisfy mission requirements at the defined milestones in the timeline.
  - Participate in project simulations where the emphasis is on the interdivisional interfaces.
- ***Launch Support Process (7)***
  - Support early mission activities by monitoring spacecraft orbit and attitude, and data related to its health and safety. Plan and execute spacecraft orbit ascent maneuvers and attitude maneuvers. Validate onboard computer (OBC) attitude and orbit compared to the ground attitude and orbit.
  - Support calibration activities by planning and executing attitude sensor calibration maneuvers, if needed. Process calibration telemetry data and estimate sensor biases and misalignments. Send the results to the flight operations team for uplink to the spacecraft.
  - Generate orbit and acquisition data products.
- ***On-Orbit Mission Operations Process (8)***
  - Perform routine on-orbit operations, special requests, and analysis as needed. Produce status reports as required.

5.0 Building Proactive QA Into the Flight Dynamics Mission Support Process

This section discusses FDO's approach, the in-progress process reviews, and the payoff involved in building a proactive quality assurance process for GSFC Flight Dynamics mission support.

5.1 Proactive QA Approach in the Form of Process Assurance

The emphasis of the FDO's QA approach is on proactive prevention of problems by the following activities:

- Build quality checkpoints into FDO project plans, work package plans, mission support phase activity plans, and product QA plans. These checkpoints with appropriate quality criteria ensure that all pertinent activities are quality assured during the process before moving into the next phase of work.
- Provide and/or assist in PPRs to project leader and POMs with just-in-time training to the technical staff before the start of a project or mission support phase and ensure awareness of quality checkpoints by technical staff.
- Monitor the work and/or mission support phase processes and detect any deviations from the established processes and quality standards so that corrective action can be taken as early as possible in a mission or project life cycle. Regular internal mission reviews, IPPRs, preliminary reviews, dry runs before formal reviews, walkthroughs, and peer reviews are in this category.
- Ensure compliance with all policies, standards, and procedures for all processes, products, and services.
- Collect quality-related data, analyze, and feedback for process improvement. Coordinate with the FDO's Defect Causal Analysis (DCA) and Lessons Learned programs.

A comprehensive QA approach is implemented at the FDO mission support project and task levels. An FDO mission support project is a task or a set of tasks involved in a given Flight Dynamics mission. An FDO mission support plan, prepared by a mission manager or project leader, defines all the major Flight Dynamics activities and

events that occur during the development and initial deployment of a mission. One example of this proactive approach is the conducting of IPPRs as described in Section 5.2.

5.2 IPPRs for the FDO Mission Support Life Cycle

The IPPRs are performed for all six phases of the FDO mission support life cycle. The IPPR assesses project team members' understanding of and conformance to the S&Ps and provides an LCPA checklist for the mission-or project life cycle phase. The review occurs approximately 15 to 25 percent into the calendar schedule of the mission support life cycle phase. The PAO uses the mission phase-specific checklist to evaluate the phase activity progress. An assessment guideline for each phase has been set to an 80 percent or higher satisfaction level to determine whether the phase activities are on track. This guideline has proven to be achievable.

Quality/process checklists were developed for the IPPR using the FDO mission support JIT training materials. The FDO Mission Support process coordinator and associates offer this JIT training to the mission teams before the beginning of each phase of the FDO mission support life cycle. PAO participates in training coordination. The training normally occurs 2 to 3 weeks before the start of each phase. These mission phase IPPR checklists are updated and enhanced periodically using the feedback comments from the project leaders, mission managers, team members, and lessons learned. Two sample IPPR checklists for the operations planning and training, and launch support phases are as shown in Tables 1 and 2, respectively. The questions labeled as P1, P2, and P3 were added to collect additional comments or suggestions for the process and overall assessment.

5.3 Proactive QA and Payoff

The quality approaches too often have been reactive rather than proactive in industry as a whole. Therefore, the cost has been high and the reactive QA also caused delays in the delivery schedule. The proactive quality approach, on the other hand, builds quality assurance into the work processes as the mission support life cycle progresses. While the reactive approach deals with the end products, the proactive approach deals with the processes, which prevents errors or rework. In this way, errors and inefficiencies can be detected earlier and corrected quickly, preventing excessive rework after a product is produced. Results of high-quality work from one phase will provide a sound foundation for the subsequent phase. The proactive quality assurance costs are small and repay well in quality products and services and timely delivery. Currently a little more than one PAO staff member has been supporting 150 FDO staff members effectively. The impact of process assurance activities on the quality of the final products and services could be considered minor; while the prime responsibilities are performed by the mission team. However, the cost savings via the process assurance could be significant to the multimillion-dollar space missions.

6.0 Actual Implementation and Findings

Over the past few years, CSC's FDO has implemented a comprehensive proactive QA process applied to each of six phases of the Flight Dynamics mission support life cycle and the documents produced during each phase. As advocated, the quality approach has been proactive rather than reactive. In this way, errors, inefficiencies, and, therefore, rework have been prevented, and quality products and services were delivered on time. This subsection presents the status of how often and to what missions those proactive QA processes were applied (i.e., PPRs, POM, coordination of JIT training, internal mission reviews, dry runs or preliminary reviews before formal reviews, walkthroughs, audit coaching, IPPRs, and LCPA). It is difficult, if not impossible, to measure numerically the results or effectiveness of the processes. However, the proactive QA process has been well received by the line management and technical staff. It has served as a useful reminder on aspects of the process that can be forgotten in day-to-day work. The impression of the perceived improvement has been good as expressed by the mission managers. The FDO missions supported recently by this process were SAMPEX, Deep Space Program Science Experiment (DSPSE), Geostationary Operational Environmental Satellite (GOES) -I and -J, WIND, POLAR, X-ray Timing Explorer (XTE), and Solar and Heliospheric Observatory (SOHO) that were launched successfully, and Submillimeter Wave Astronomy Satellite (SWAS), Fast Auroral Snapshot Telescope (FAST), Total Ozone Mapping Spectrometer (TOMS), Tropical Rainfall Measurement Mission (TRMM), Advanced Composition Explorer (ACE), Wide-Field Infrared Explorer (WIRE), and Earth Observing System (EOS) that are to be launched in the near future.

Table 1. IPPR Checklist for the FDO Operations Planning and Training Phase

Question Number	Question
1	Have you established a training coordinator, a training plan, and discussed the training plan with your ATR(s)?
2	Has the team begun drafting procedures and is there a central repository for these procedures?
3	Has a mechanism been established to track action items?
4	Has a readiness matrix been prepared? (Coordinate with the Flight Dynamics Institution of Simulation and Training (FIST) group.)
5	Have you contacted the mission coordinator concerning the development of the Mission Support Plan (MSP)?
6	Were any lessons learned recorded for this phase?
7	Have any software problems that were detected (during use for training and simulations) been documented and provided to the development/maintenance personnel? What is the resolution status?
8	What will be the products produced and Standards & Procedures (S&Ps) applied?
P1	Was the JIT training adequate to start the phase?
P2	Any other problems encountered in this phase or suggestions?
P3	Overall Assessment: P.1 Is the phase support on track? P.2 If not, what is the resolution?

Table 2. IPPR Checklist for the Launch Support Phase

Question Number	Question
1	Who is the central contact point during the launch support?
2	What is the chain of reporting in the Flight Dynamics Facility (FDF) for emergency (within CSC and with the GSFC chain)?
3	What are the launch support components, group leaders and members, and communications required between the component groups?
4	What shift groups are there, who are the members and leaders, and are phone numbers available?
5	What are the unique nature and requirements of this launch support?
6	What are recent procedure changes and terms are not familiar to everybody on the team?
7	What are the interfaces external to FDF, communications/data transfers required, and different terms used?
8	What are the potential problems or mishaps and resolution (or mitigation) strategy? Do all the team members know how to respond to those emergencies or contingencies?
9	Have you obtained any lessons learned from the previous missions and team members for this mission support?
10	Are there any problems or pending items that make the team uneasy at this point?
P1	Was the JIT training adequate to start the phase?
P2	Any other problems encountered in this phase or suggestions?
P3	Overall Assessment: P.1 Is the phase support on track? P.2 If not, what is the resolution?

The examples in Table 3 show various types of in-progress reviews conducted at different stages of the life cycle phases for the XTE mission. An IPPR was not conducted for every phase of the entire mission life cycle. The reviews supported were performed only when PAO had available time; therefore, the lists are not as complete as they could be.

Table 3. FDO In-Progress Reviews for the XTE Missions

Review	Date
Requirements and Specifications Phase IPPR	04/08/93
Software Development Support Phase IPPR	09/01/93
Project IPPR	04/21/95
DORR (L–60)	06/29/95
DORR (L–30)	07/27/95
Launch Phase PPR	07/28/95
Launch Phase POM	07/31/95, 12/05/95
Operations Planning and Training Phase IPPR	11/21/95
XTE Launch	12/30/95
Lessons-Learned Workshop	03/29/96

In addition to the reviews listed in Table 3, FDO internal mission reviews are performed regularly (for example, once or twice a month with the FDO management until launches). The PAO attends these review meetings. After IPPRs, DORRs, LCPAs, and other reviews, PAO writes review reports and distributes copies to the project or mission team leader. Lessons learned data are used for process improvement and are disseminated to the next mission teams. The project or mission managers are interviewed before and after the launch to evaluate the impacts of PAO's reviews. They have made the following observations:

- The FDO PAC procedure provides a comprehensive reminder list for the phase activities while the team members are otherwise occupied.
- The PAO review motivates FDO mission manager and team members to move on to the next phase. Occasionally, the team experience some difficulty starting up a new activity following the completion of a phase.
- The review educates new mission managers who have not managed the entire mission support life cycle.
- JIT training before the phase was useful to mission managers and team members.
- Coordination or providing lessons learned for the mission manager and team was helpful.
- Knowing ahead of time about the lessons learned from the previous missions was helpful for the mission manager and team when planning future resolutions.
- The prelaunch readiness review meeting improved the morale of the team and helped team building.

The following were lessons learned:

- JIT training needs to be done at the right time (but it is difficult to define that time), and JIT needs to be repeated or spread throughout the phase with different emphasis; overview, details, and refresher.
- Deployment of the process was suggested to all members of the organization rather than limited to mission managers or project leaders.

The survey continues and feedback comments are collected in FDO for both the process itself and associated checklists. The same in-progress process assurance principle as used in the mission support phase IPPR has been applied to FDO document quality via the Product QA Plan. In the Product QA Plan, quality checkpoints are identified and appropriate quality criteria are provided ahead of time for QA reviewers.

7.0 Document Reviews and FDO Product QA Plan

Another aspect of FDO process assurance is to ensure that documents produced are quality assured and to provide the QA reviewers some guidance on how to perform the QA. One of the primary approaches to achieving technical quality in products is the FDO Product QA plan. Products include documents, memoranda, technical papers, and presentation materials. The Product QA Plan form for each FDO deliverable product includes key steps that verify

whether an appropriate QA reviewer has been selected, S&Ps have been identified, QA checkpoints have been identified with appropriate QA checklists (both generic and document-specific) attached, coordination with FDD Configuration Management Office (CMO) and Technical Publications has been scheduled, and QA data collection has been planned for analysis.

The QA reviewer may be anyone in the FDO who is technically qualified to perform the review and who does not report administratively to the line manager responsible for the product. The intent of this review is to ensure the technical quality of products, but their appearance and adherence to schedule may also be reviewed.

In the FDO Product QA Plans, key quality review steps or checkpoints are identified and the corresponding quality criteria are attached for document reviews such as for system and operations concepts, requirements specifications, functional specifications, mathematical specifications, presentation slides for SOCR, SRR, and DORR, mission support plan, analysis reports, professional paper, etc. The QA reviewers then use the quality criteria to review the documents. The Product QA Plan form and associated QA checklists have been updated and enhanced periodically using the feedback comments from the QA reviewers and authors, and lessons learned. Historically, lists of document quality criteria were developed in FDO earlier than the IPPR checklists for the Flight Dynamics mission support life cycle phases. Some of the document quality criteria were used to generate phase IPPR checklists as mentioned earlier in the paper.

An example of specific quality criteria for a requirements specifications document (used with an FDO Product QA Plan) is shown in Table 4. In the document review process, general QA categories are also incorporated such as for technical accuracy, internal consistency, conciseness, freedom from redundancy, clarity, and adherence to the established standards and format.

Table 4. Quality Criteria for the Requirements Specifications Document

Criteria Number	Criteria
1	Are the DMR and related studies referenced when necessary?
2	Are all requirements defined for all mission phases?
3	Are the assumptions reasonable and precisely stated?
4	Does the requirements summary correctly trace requirements to a high level source document?
5	Does the requirements summary include all requirements critical to the definition of the system and operations concepts?
6	Are items such as major external interfaces summarized?
7	Is there consistency between the high-level and low-level requirements?
8	Does the document provide complete information to facilitate the following: • The analysts in preparing functional specifications? • The analytical and acceptance test teams in preparing test plans?
9	Other (Specify)

8.0 Process Improvement Through Lessons Learned

Each mission team within the FDO is responsible for developing and documenting improvements and continuing good practices based on the lessons learned during day-to-day activities or during the generation of products and services. The vehicles used to deploy lessons learned are the project lessons learned database, the FDO lessons learned database, reports, electronic files or bulletin boards, training, and DCA reports. These lessons learned are fed back into the process for continuous improvement. The PAO identifies and evaluates S&Ps that are appropriate for FDO products and services. It also establishes and/or assists in developing S&Ps for FDO products and services when appropriate S&Ps do not already exist. The PAO promotes communication among FDO projects and/or missions on tools and methodologies that may contribute to improved quality and productivity. A continual effort is made to improve process assurance and quality assurance methodologies for the FDO-unique mission analysis and support activities. Process and QA methodology changes include those due to changes in mission requirements,

institutional changes, and lessons learned. Methodology effectiveness is closely monitored and evaluated for improvement.

A few examples of the lessons learned that contributed to the FDO process improvement are as follows. The IPPR checklist for the launch support phase (Table 2) was improved after it was learned that other NASA centers, ground stations, and the European Space Agency (ESA) often use different terms from those used at GSFC. A prelaunch readiness review or phase orientation meeting with the PAO-generated review item check list was very positive in team building and morale boosting for the DSPSE mission. Since then, the GOES-I, GOES-J, WIND, SOHO, XTE, and POLAR mission teams used this process. Concerning FDO document reviews, it was observed (in general) that the review results vary depending on the QA reviewers even after a review checklist was given ahead of time. Document review skills training is being considered in FDO.

9.0 Summary and Recommendations

The FDO PAC procedure incorporates process/quality checklists for each of the six FDO mission support life cycle phases. The findings from the actual implementation of the phase IPPRs showed that perceived quality improvement and feedback comments have been very positive. The intermediate results have been good. For further improvement to the FDO process assurance, it is recommended to (1) implement all in-progress process reviews over the entire life cycle from concepts to on-orbit mission operation phase, (2) devise a scheme to measure the cost of this process compared with the total mission cost, and (3) adapt the FDO PAC model to the needs of evolving technology—commercial off-the-shelf software, personal computers and/or workstations, and joint application development (JAD) or rapid application development (RAD) approaches. In the areas of FDO product QA, more training must be provided for authors as well as QA reviewers concerning the QA checkpoints, quality criteria and review skills. The proven processes and lessons learned need to be promulgated throughout FDO.

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