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January 23, 1998

The Honorable Ernest F. Hollings
Ranking Minority Member
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Wendell H. Ford
Ranking Minority Member
Subcommittee on Aviation
Committee on Commerce, Science, and Transportation
United States Senate

Subject: Air Traffic Control: Timely Completion of FAA's Standard Terminal Automation Replacement System Software Is at Risk

We briefed your offices on October 24, 1997, on our review of the Federal Aviation Administration's (FAA) Standard Terminal Automation Replacement System (STARS) software. A copy of the materials presented during that briefing is enclosed. Our review objectives--refined through discussions with your offices--were to examine (1) the composition, status, and quality of STARS software and (2) potential risks to timely, successful completion of STARS software.

To address these objectives, we interviewed staff from FAA and its prime software development contractor, Raytheon Electronic Systems, at Raytheon's Marlborough, Massachusetts, facility. We analyzed project documentation concerning key acquisition and process development areas and indicators of product quality, such as results of software quality assurance audits and trends in reported defects. We also analyzed project office and contractor reports addressing progress against cost and schedule plans and budgets. We did not evaluate the reliability of the systems that produced these reports, nor did we independently verify the numbers, costs, and dates provided by FAA or Raytheon. We conducted our work from August through October 1997 in accordance with generally accepted government auditing standards.

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OVERVIEW OF STARS COMPOSITION, STATUS, AND QUALITY

STARS is a complex, costly, and software-intensive system that is to replace aging terminal display and processing systems at 171 FAA facilities nationwide. FAA plans to implement STARS in two phases--the Initial System Configuration and the Final System Configuration--between December 1998 and June 2005 at a total development and deployment cost of about $1 billion.

There are three primary components of the STARS software: (1) full service (software enabling air traffic control functions), (2) emergency service (software providing backup should the primary system fail), and (3) transition (software for moving from the current environment to STARS). The three components are being developed in a total of four "builds."[1] The first build has been developed, while the remaining three are being developed. STARS software is to consist of over 1 million source lines of code; of this, about 85 percent is to be commercial, off-the-shelf software, with the remaining 15 percent to be modified or newly developed. The largest amount of software resides in the full service component, 70 percent of which FAA has designated as highly complex.[2] FAA estimates that STARS software development will cost over $25 million--about one-third above the original estimate.

For a number of reasons, FAA is behind schedule in developing STARS' full service software component for its initial configuration. First, software milestones were originally determined by working backwards from a predetermined date for implementing the initial configuration that was based on when the existing system would no longer be reliable, rather than being estimated as a function of the size and complexity of the software development effort.[3] Second, the new/modified full service component (measured in source lines of code) is now estimated to be 50 percent larger than the original November 1996 estimate. Third, Raytheon was slow in staffing the project. For example, although the contract with FAA was signed in September 1996, no

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[1]Software "builds" are a series of software increments, each with increasing capabilities that add to or build upon the capabilities of the preceding increment.

[2]FAA calculated the complexity of each STARS software component based on what each component had to do and the number of interfaces it needed, multiplied by a weighting factor.

[3]We recommended that FAA institutionalize defined estimating processes in our report Air Traffic Control: Improved Cost Information Needed to Make Billion Dollar Modernization Investment Decisions (GAO/AIMD-97-20, January 22, 1997).

software manager was assigned until November. Fourth, Raytheon introduced a new corporate software development tool early in the life of the project; this delayed software development while staff learned how to use the tool. Fifth, Raytheon's actual software productivity rates were lower than projected. For example, in April 1997, software productivity was only 57 percent of Raytheon's goal of 240 lines of code developed per labor-month. Finally, Raytheon took longer than expected to specify the software requirements for builds 2 and 3 of the full service component. The software requirements specification for build 2, which was due on May 16, 1997, was completed on June 25, while the specification for build 3, which was due on June 10, was completed on September 15.

In an effort to monitor software quality, Raytheon conducted quality assurance audits of software processes. The audits focused on project planning documentation compliance, software inspections, and software development files. Raytheon has since resolved all findings resulting from these audits. In addition, Raytheon and FAA are identifying and tracking software program technical reports (PTR). Type 1 PTRs are the most severe--they are capable of preventing accomplishment of operational or mission-essential capabilities, and they could jeopardize safety and security. As of October 10, 1997, of 274 "open" PTRs, 52 percent--143 reports--were rated Type 1. For example, one report showed that the conflict alert function failed to detect alerts during a product verification test.

POTENTIAL RISKS JEOPARDIZE THE TIMELY COMPLETION OF STARS SOFTWARE

The development of STARS software entails several risks that are likely to cause further delays. First, currently scheduled completion dates for builds 3 and 4 do not reflect delays and problems that have already occurred during the development of builds 1 and 2, as discussed above. Second, software requirements have increased since the software development schedule was set. The specification of software requirements for build 3 was completed late, and the software development schedule was not adjusted to reflect the additional requirements. In addition, there could be further software requirements growth, given that computer-human interface issues are emerging.[4] Third, FAA's decision to develop builds 2 and 3 in parallel (rather than in sequence) increases the risks that problems encountered will take longer to correct since two builds will have to be modified simultaneously. Fourth, in an attempt to

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[4]Air traffic controllers have expressed dissatisfaction with the STARS computer-human interface, and FAA plans to meet with Mitre Corporation and controllers in an attempt to resolve the issues.

remain on schedule, FAA has eliminated Partial System Test 1 and compressed the schedule for other tests, including Partial System Test 2, Installation and Integration Tests, and Site Acceptance Tests.[5] Emphasizing concern for schedule at the expense of disciplined systems development and careful, thorough testing has proven to be imprudent and unproductive in many software development efforts. The results are typically systems that cost more than expected, are of low quality, and are late as well.[6] A final area of concern is Raytheon's productivity: Raytheon recently revised the software productivity goal downward by 25 percent, from 240 to 180 lines of code per labor-month. However, actual software productivity is below even the new goal. FAA officials told us that the latest data provided by Raytheon shows that software productivity is averaging 130 lines of code per labor-month.

FAA and Raytheon have acknowledged the risk that the software development schedule may slip by several months. Also, they have identified the software development schedule and computer-human interface as software-related risks in their joint risk management program. FAA and Raytheon currently have risk mitigation efforts underway, including monitoring monthly software assessment demonstrations and ranking computer-human interface changes through regular meetings.

On December 18, 1997, we obtained oral agency comments on a draft of this letter from the Department of Transportation and FAA. The Department of Transportation and FAA generally agreed with the facts presented, and their comments have been incorporated where appropriate.

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As agreed with your offices, unless you publicly announce the contents of this letter earlier, we will not distribute it until 30 days from its date. At that time, we will send copies to the Chairmen and Ranking Minority Members of the Senate and House Committees on Appropriations; the Chairmen of the Senate Committee on Commerce, Science, and Transportation and its Subcommittee on Aviation; the Secretary of Transportation; the Department of Transportation's

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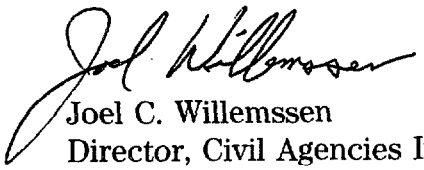
[5]According to a STARS program official, testing that was to occur as part of Partial System Test 1 is now planned for the System Acceptance Test.

[6]In Air Traffic Control: Immature Software Acquisition Processes Increase FAA System Acquisition Risks (GAO/AIMD-97-47, March 21, 1997), we made recommendations to address weaknesses in FAA's software acquisition processes that have contributed to FAA's past failures to deliver promised system capabilities on time and within budget.

Inspector General; the Administrator of the Federal Aviation Administration; the Director of the Office of Management and Budget; and other interested parties. Copies will also be made available to others upon request.

If you have any questions, please contact me at (202) 512-6253, or Colleen Phillips, Assistant Director, at (202)512-6326. We can also be reached by e-mail at *willemssenj.aimd@gao.gov* and *phillipsc.aimd@gao.gov*, respectively.



Joel C. Willemssen
Director, Civil Agencies Information Systems

Enclosure

Briefing on FAA's Standard Terminal Automation Replacement System (STARS)

October 24, 1997

GAO

Overview[a]

- Background
- Objectives
- Software Composition
- Software Plans and Status
- Software Quality
- Software Risks
- Software Processes
- Observations

[a] All of the numbers, costs, and dates cited in the briefing were provided by FAA or Raytheon and have not been independently validated by GAO.

GAO Background

- STARS is to replace aging terminal display and processing systems at 171 FAA facilities; contract was awarded to Raytheon in September 1996.
- STARS estimated development and deployment cost is about $1 billion (contract cost--$89.4 million, $25.4 is software), and deployment is planned between December 1998 and June 2005.
  - Initial System Configuration (ISC) is to be deployed at 3 sites from 12/98 through 8/99.
  - Final System Configuration (FSC) is to be deployed at all sites between 1/00 and 6/05.
- FAA recently reported that STARS software development is behind schedule; Raytheon has revised the software development schedule.

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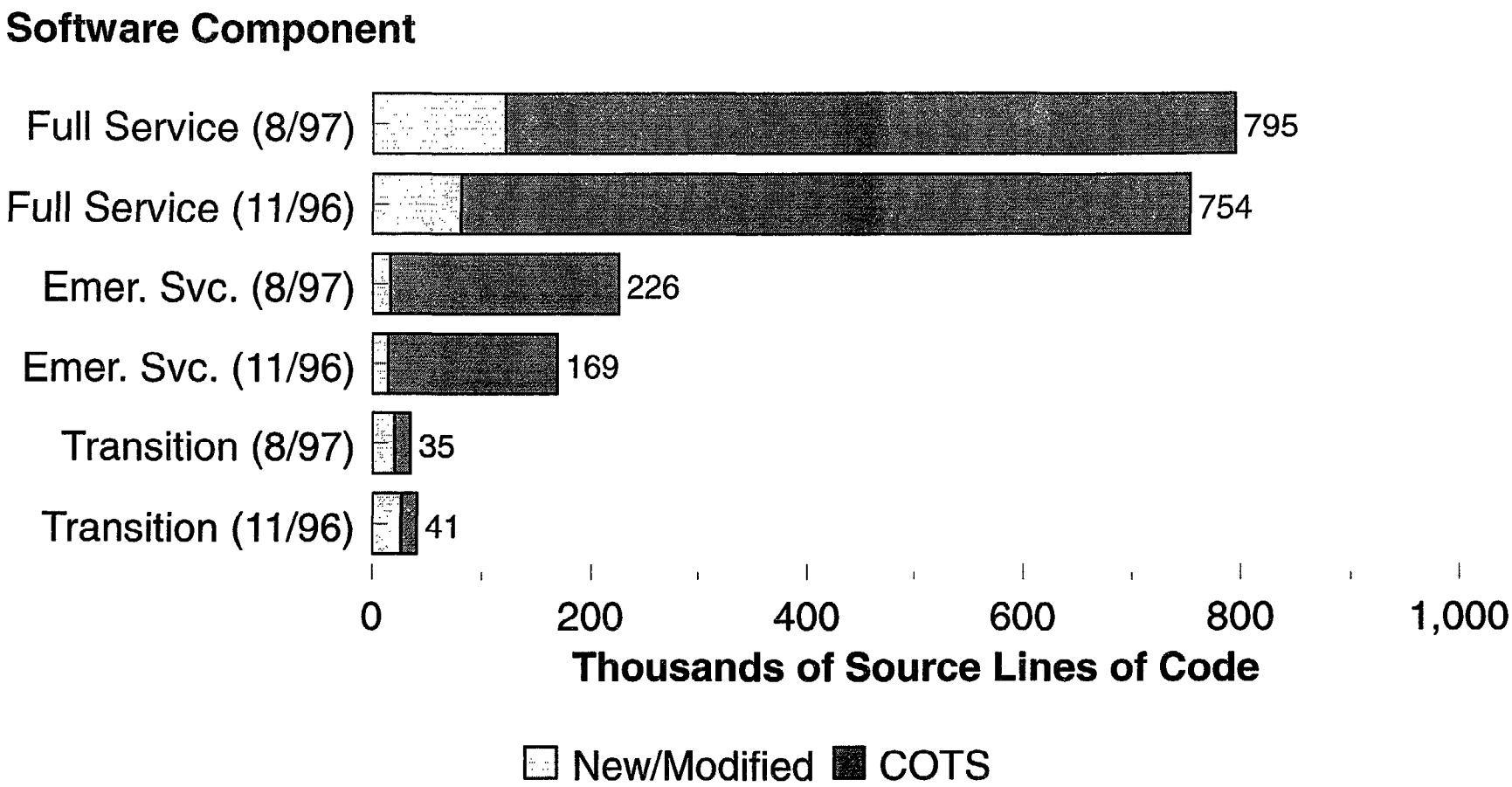
Objectives

- Examine the composition, status, and quality of STARS software.
- Examine potential risks to timely, successful completion of STARS software.

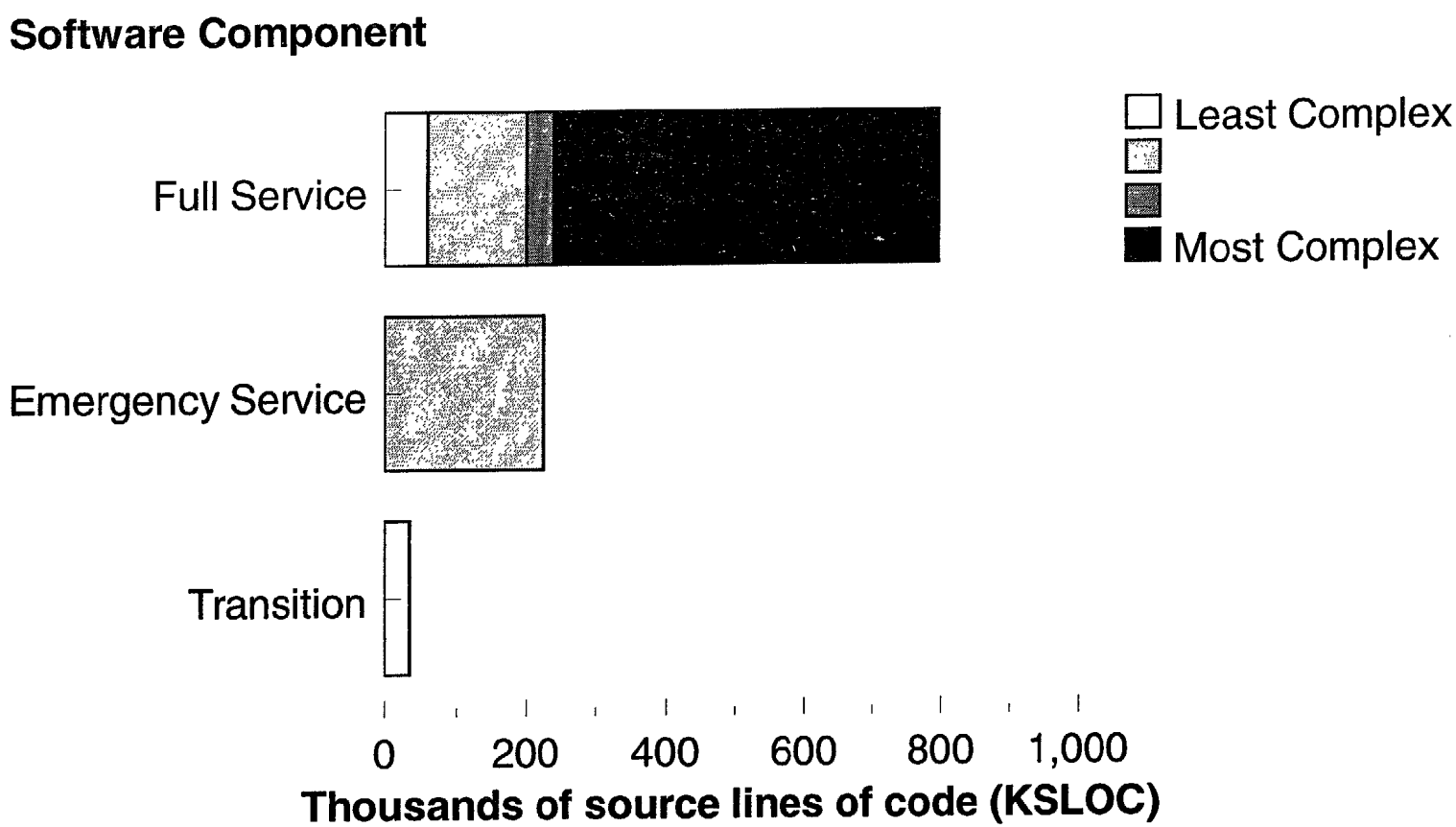
GAO Software Composition

- STARS is based largely on commercial, off-the-shelf (COTS) air traffic control software packages.
- Some new software development is needed to integrate packages and provide FAA-unique capabilities (e.g., size of U.S. airspace).
- STARS employs an open systems architecture; written in the C programming language.
- STARS software consists of 1.08 million source lines of code (SLOC) (162,000 new/modified and 916,000 COTS).
- Three major software components:
  - Full Service software (based on "AutoTrac" by Raytheon),
  - Emergency Service software (based on "TracView" by Hughes), and
  - Transition software (FAA-unique).

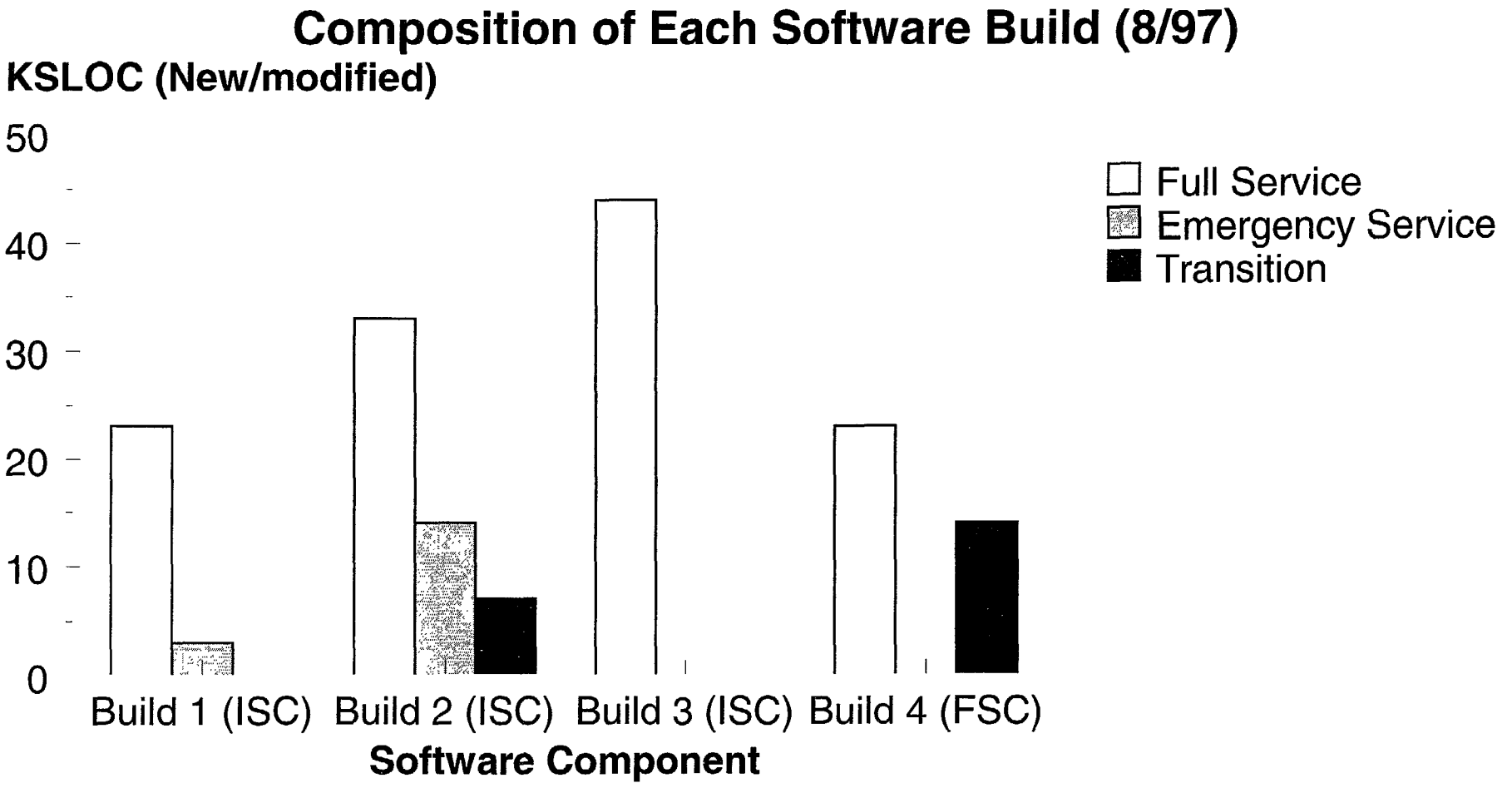
GAO Software Composition: Size (8/97 vs. 11/96)



GAO Software Composition: Complexity



GAO Software Composition: Incremental Builds



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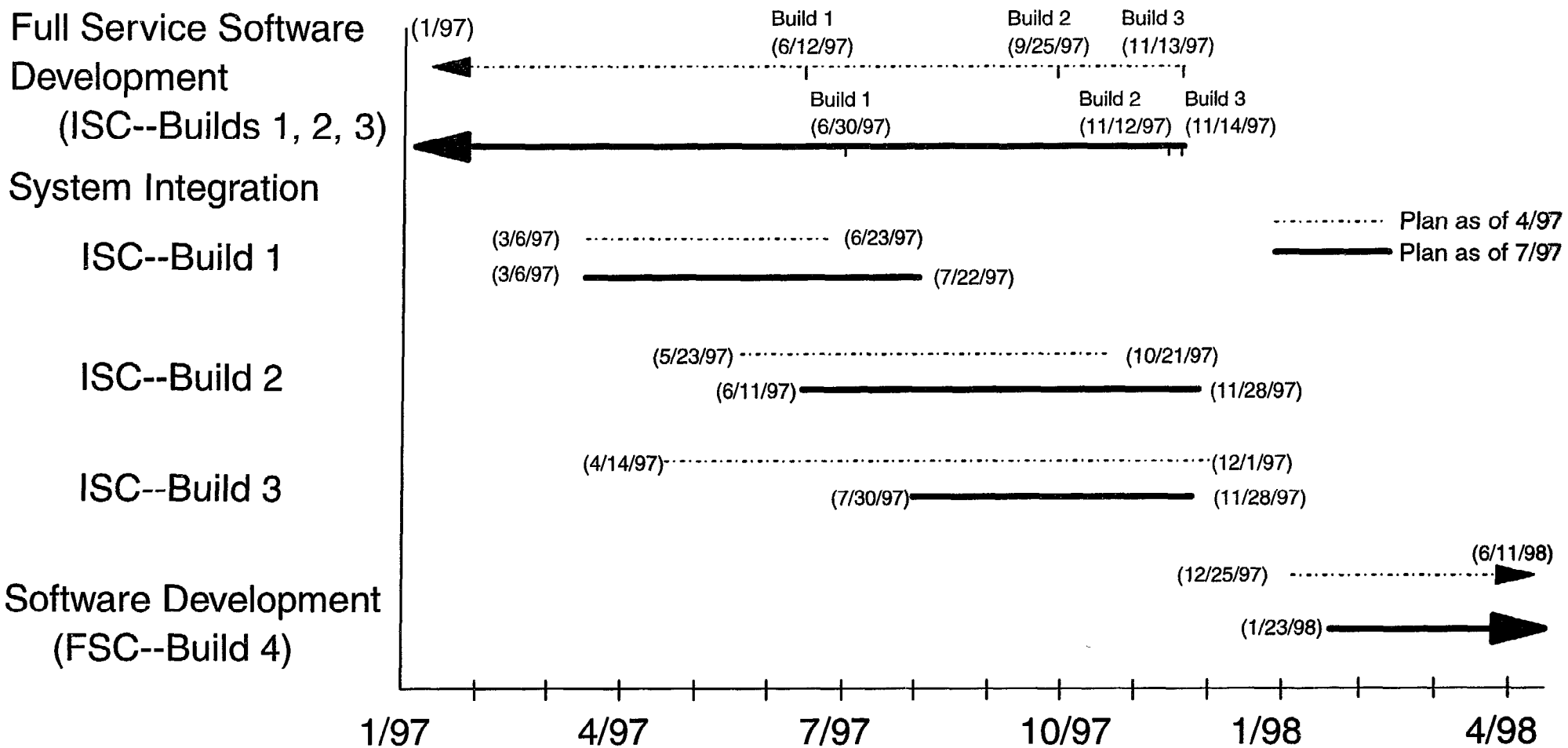
Software Development Plan and Status



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Software Plans and Status: Reasons for Schedule Delays

- Software milestones were driven by ISC date, rather than size and complexity of effort.
- The amount of new/modifed software for the Full Service component has increased by 50% over the original estimate.
- Raytheon was slow in staffing (contract awarded 9/96; no software manager until 11/96).
- Raytheon introduced a new corporate software development tool.
- Raytheon's actual software productivity rates were lower than projected (137 SLOC per labor-month in April 1997 vs. goal of 240 SLOC per labor-month).
- Raytheon took longer than expected to develop the software requirements specification for Full Service build 2 (6/25/97 vs. 5/16/97) and build 3 (9/97 vs. 6/10/97).

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Software Status: Cost

- Software development contract cost is projected to be $25.4 million, 31 percent above original estimate of $19.4 million.
  - 40% of the $25.4 million has been spent as of 7/27/97.
- Development phase contract cost is projected to be $89.4 million, 12 percent above original estimate of $79.6 million.
- Uncertainty of original cost estimates identified as a risk.

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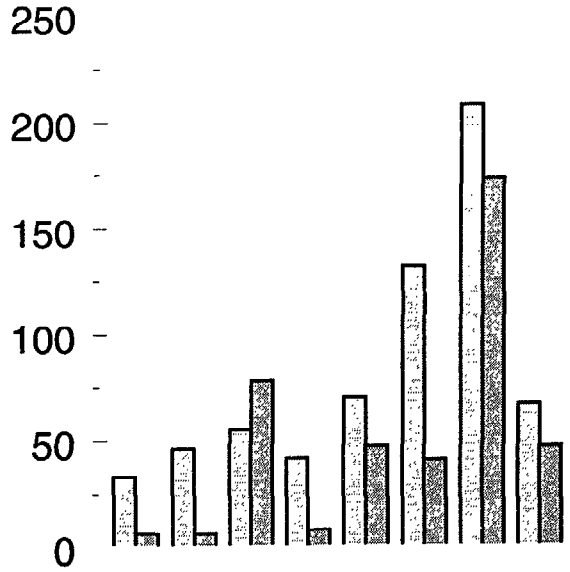
Software Quality

- Raytheon has conducted several software quality assurance audits; all findings have been closed; none appear to be significant.
- As of 10/10, there are 274 open program technical reports (PTR).
  - 143 PTRs (52%) are rated Type 1, the most severe.
  - Type 1 prevents the accomplishment of an operational or mission-essential capability, and could jeopardize safety and security.

GAO Software Quality: PTR Trends

PTRs Opened and Closed Per Month

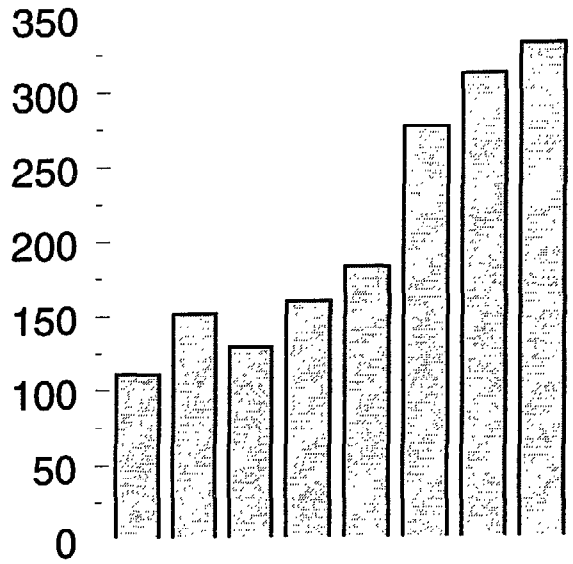
Number of PTRs



Months	1/97	2/97	3/97	4/97	5/97	6/97	7/97	8/97
PTRs Opened	33	46	55	42	70	132	208	67
PTRs Closed	6	6	78	8	47	41	173	47

Total Open PTRs Per Month

Number of PTRs



Months	1/97	2/97	3/97	4/97	5/97	6/97	7/97	8/97
Total Open PTRs	111	152	129	160	183	277	312	332

GAO Software Risks

- Top 9 program risks have been identified and are being managed jointly by FAA and Raytheon.
- Two software-related risks are rated "high" for potential cost and schedule impact:
  - software development schedule and
  - computer human interface (usability of controller displays).
- FAA/Raytheon risk mitigation efforts underway:
  - Develop and integrate software builds more concurrently, assign "hand-picked" contractor personnel, and monitor monthly software assessment demonstrations, and
  - Identify issues, determine resolutions, and rank needed changes through ongoing, joint FAA/contractor meetings.

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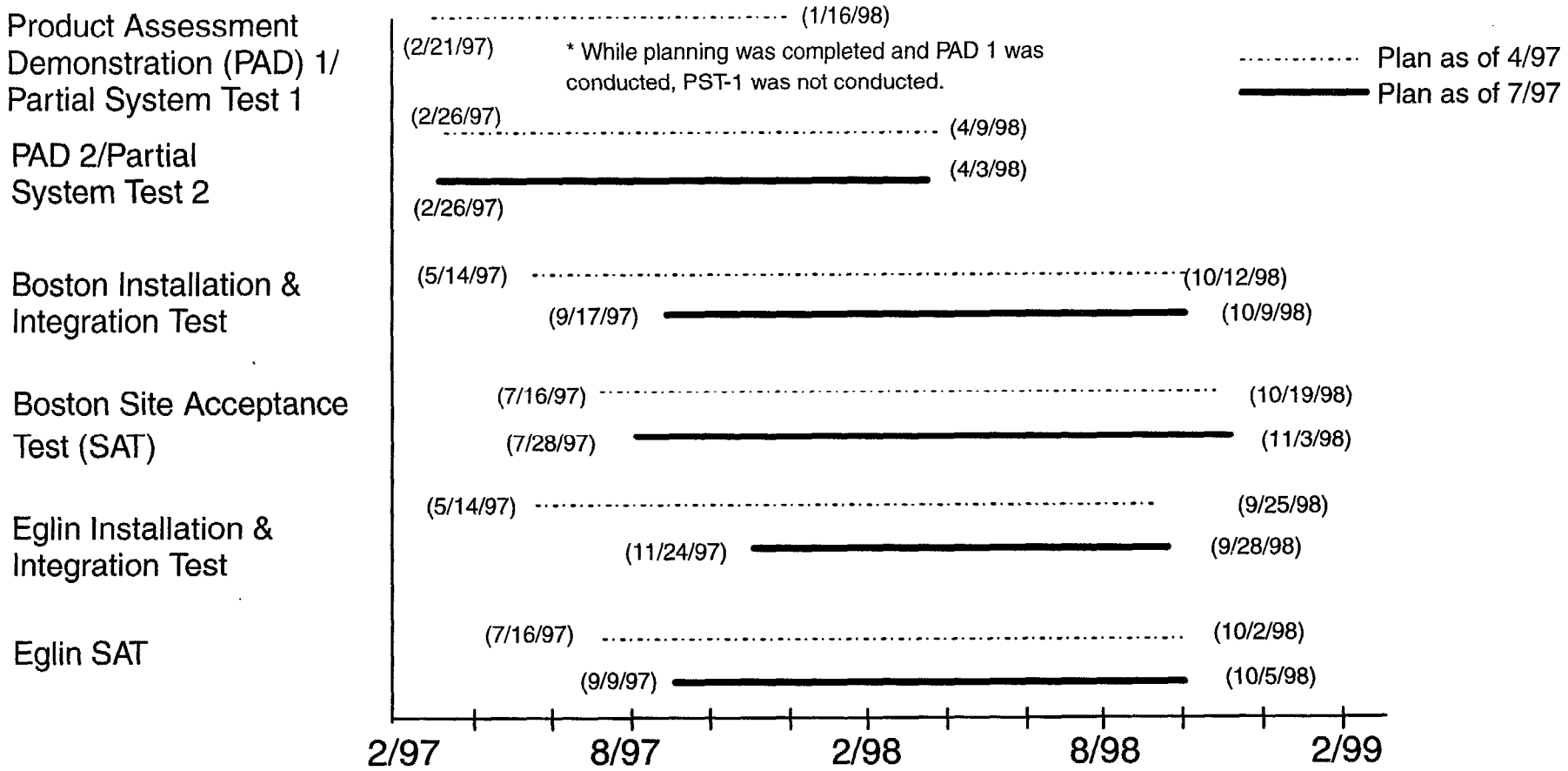
Software Processes

- GAO did not conduct a formal SA-CMM evaluation of FAA or a SW-CMM of Raytheon.
- FAA/Raytheon performing key software activities (e.g., risk management, quality assurance, configuration management, requirements management).

GAO Software Processes

- Some ISC test activities being compressed or eliminated



GAO Observation

Further ISC development delays likely for several reasons

- Current completion dates for builds 3 and 4 do not recognize impacts of builds 1 and 2 problems and delays.
- Software requirements could grow more (build 3 software requirements specification was completed late and user interface questions emerging).
- Risk mitigation strategy--parallel development of builds--actually increases software risks.
- Elimination and compression of testing also increases risks.
- FAA officials stated that actual software productivity rates are 130 SLOC per labor-month, still below revised goal of 180 SLOC per labor-month.

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