STS-112 / 9A
Flight Readiness Review

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Johnson Space Center
September 17, 2002

Agenda

- **STS-112 / 9A – G. Guirgis**
  - EVA Mission Overview
  - EMU and SAFER Logistics
  - EMU and SAFER Status
  - EVA Tools and Crew Aids Manifest Summary
  - EVA Fit checks and Sharp Edge Status
- **EVA Project Office Special Topics – G. Lutz**
  - EMU Battery In-flight anomaly
  - Pistol Grip Tool Low Torque
    - Structures and Mechanism impacts to Pistol Grip Tool (PGT) issue – G. Gafka

EVA Mission Overview

- **EVA Capability**
  - EVA consumables to support
    - Three scheduled EVA's
    - One unscheduled EVA for mission success tasks not completed or ISS contingencies
    - Two contingency EVA's for orbiter, Remote Manipulator System (RMS), and Orbiter Docking System (ODS) contingencies
- **EVA Training**
  - Crew is fully trained on all EVA tasks
  - Includes the late addition of new EVA tasks (i.e., Interface Umbilical Assembly (IUA) R&R and Spool Positioning Device (SPD) installation)
  - All EVA1, EVA2, and EVA3 tasks can be accommodated within the scheduled 6 hours 30 minutes timeline

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EVA Mission Overview (cont.)

- **EVA 1 (Flight Day 4) – 6 hours 30 minutes**
  - Zenith utility tray mate
    - Both zenith and nadir trays must be connected prior to the end of EVA1
  - Radiator beam launch lock release
    - 18 launch locks need to be released prior to end of EVA2 to allow rotation of the radiator beam
  - S-Band Antenna Support Assembly (SASA)
    - Must be relocated prior to end of EVA1 to provide keep alive power
  - Crew and Equipment Translation Assembly (CETA) Cart launch locks
    - CETA cart required for fluid jumper install on EVA3
  - S1 outboard nadir camera install
    - Required for Space Station Remote Manipulator System (SSRMS) Ops on ULF-1
  - Nadir tray mate

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EVA Mission Overview (cont.)

- **EVA 2 (Flight Day 6) – 6 hours 30 minutes**
  - Z1-P6 (2 x 1”) and Solar Array Radiator (2 x 1”) Spool Positioning Device (SPD’s)
    - Loop A wet 1” Quick Disconnects (QD’s)
  - Z1 to Lab loop A (2 x 1”)
  - Ammonia Tank Assembly (ATA) umbilical connection and SPD installation
    - Connect Ammonia tank to Nitrogen tank and Pump Module (PM)
    - Install 0.5” SPD
  - Lab camera install
    - Forward / starboard end of Lab
  - SPD installation on radiator beam valve module
    - 18 x 1” SPD’s
  - Final launch lock released
- **Total SPD’s: 25/31**

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EVA Mission Overview (cont.)

- **EVA 3 (Flight Day 8) – 6 hours 30 minutes**
  - Interface Umbilical Assembly (IUA) R&R
  - S1 to S0 fluid jumper install
    - 4 x 1.5” SPD’s installed
  - Port and starboard drag link and keel remove and stow
    - Required for Mobile Transporter/Mobile Remote Servicer (MT / MBS) translation onto S1 truss for S3 installation
  - Thermal Radiator Rotary Joint (TRRJ) stinger SPD’s
    - 2 x 1.5” SPD’s
  - TRRJ stinger bolts
    - Required for trouble shooting of the TRRJ
  - Squib Firing Unit (SFU) reconfiguration
    - Provides redundant heater power to radiator fluid lines
  - S1 / S3 line clamps
    - Required for S1 / S3 utility line connection
- **Total SPD’s: 6/31**

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EMU and SAFER Logistics

- **Two EMU's Launched on 9A (XL, XL)**
- **Three EMU's On-orbit Prior to 9A Docking (M, L, L)**
  - One Large (ISS) and one X-Large (SSP) used for 9A docked EVA's
- **Two EMU's Returned on 9A (XL, XL)**
  - To support Wolf and Sellers during a contingency EVA
- **Three EMU's On-orbit Post 9A Undock (M, L, L)**
  - Increment 5 EMU hardware for Korzun, Treschev, and Whitson left on ISS post UF-2
- **One SAFER Manifested / Two SAFER's On-orbit**
  - Increment 5 will checkout the two on-orbit SAFER's for 9A use
  - One SAFER (S/N1004) launched in Middeck for rotation with one (S/N1005) unit on-orbit

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EMU and SAFER First Flight and Open Items

- **EMU and SAFER First Flight Hardware**
  - None
- **EMU Failures, Waivers, or Certification Issues**
  - None
- **SAFER Failures, Waivers, or Certification Issues**
  - None

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EVA Tools and Crew Aids Manifest Summary

- **EVA Tools and Crew Aids First Flight Items**
  - CETA Cart and associated outfitting (1)
  - 0.5” (2), 1.0” (28), and 1.5” (13) SPD's
  - Tether shuttles (2)
  - QD vent tool bag (1)
    - Bail drive lever tool (1)
    - 0.5” and 1.0” QD cap removal tool (2 each)
    - 1.0” and 1.5” QD release tool (2 each)
    - 1.5” bail drive lever tool (2)
- **Non-GFE EVA Hardware First Flight Items**
  - None
- **EVA Tools and Crew Aids Failures, Waivers, or Certification Issues**
  - Open certification for 0.5” SPD (ECD 9/20/02)
  - PGT – out of calibration issue, to be covered under special topics

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EVA Tools and Crew Aids Manifest Summary

- **EVA Tools and Crew Aids Swapped / Left / Returned**
  - Coordinated with ISSP- List of items in Backup Charts
- **Standard Contingency Tools in Port Light Weight TSA**
  - Plus two EVA tether shuttles
- **Portable Foot Restraint (PFR) Configuration - None**
- **Standard complement of slidewires, safety tethers, crew hook locks, and winches in payload bay**

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EVA Fit Checks and Sharp Edge Status

- **Tool-to-tool Fit Checks**
  - 100 percent complete
- **Tool-to-Interface and Interface-to-Interface Fit Checks**
  - 100 percent complete (with exception of SPD's)
    - Due to the late development of this requirement, no flight SPD's were fit checked to their respective matching flight QD's. High fidelity SPD's were fit checked to P1 hardware for verification based on similarity.
    - Risk of open fitchecks has been agreed to by ISSP
- **Sharp Edge Inspections**
  - Sharp edge inspection complete

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EMU Battery Issues

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EMU Battery Anomaly

- **Background**
  - EMU Increased Capacity Batteries (ICB's) have experienced several instances of less than expected capacity
    - Most dramatic was S/N 2022 which had rapidly dropping voltage during STS-111 / UF2 EVA2. EVA was successfully completed however, battery capacity was less than the EVA requirement.

Silver Zinc
Increased Capacity Battery

ICB Cell
(11 Cells Per Battery)

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EMU Battery Anomaly

- **Status**
  - Battery Summit was held at JSC on July 23–26, 2002, to understand issues with EMU battery capacity
  - Have identified three (3) most probable root causes for the anomaly experienced (less than expected capacity)
    - Interrupted charging
      - Occurs when battery charging is interrupted before voltage reaches maximum
        - » Results in 10 percent permanent loss of capacity
    - Storage in semi-charged state
      - Previous battery experience considered that a silver zinc battery was discharged after an EVA
        - » Recent experience has shown that sufficient power remains after an EVA to degrade future battery performance (growth of oxalate crystals causing internal anode-cathode shorts)
    - Self-Discharge
      - Loss not considered a factor in the past due to short Shuttle flights, EMU checkout top-off charges and ground processing freezer storage
        - » Loss can become significant with storage aboard ISS (estimated to be ~5 percent capacity loss per month)

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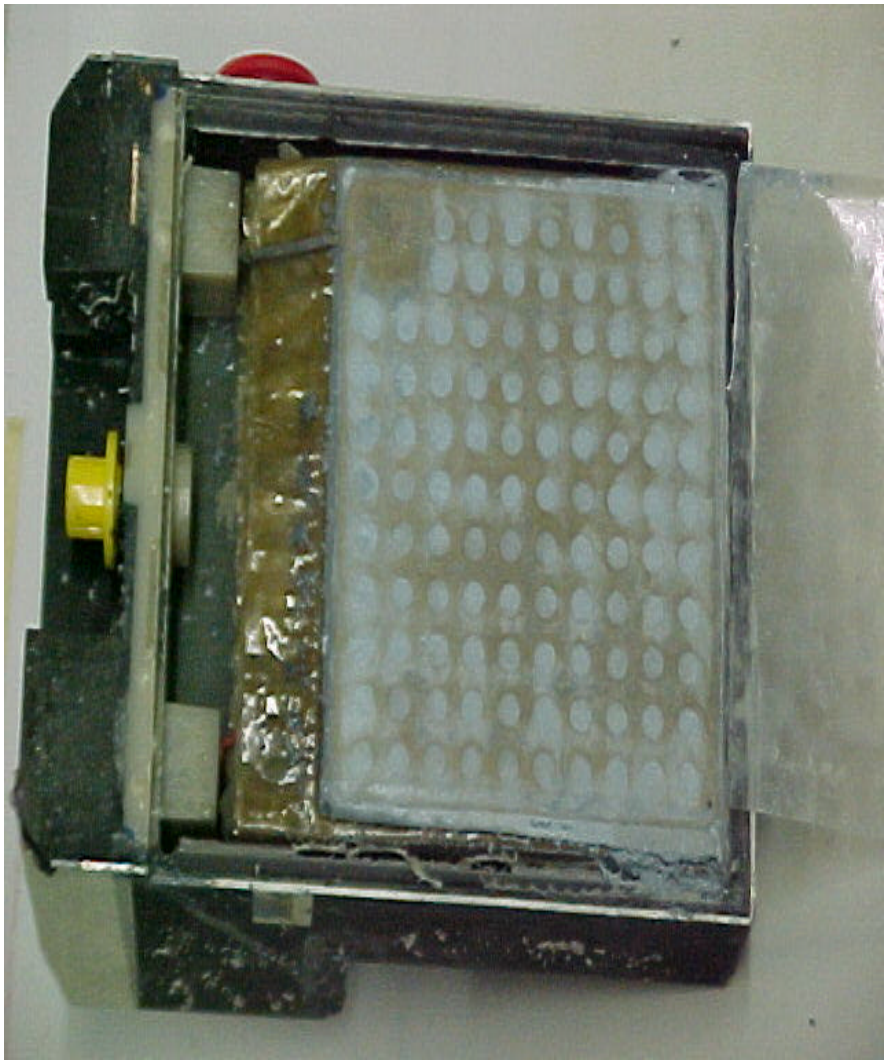
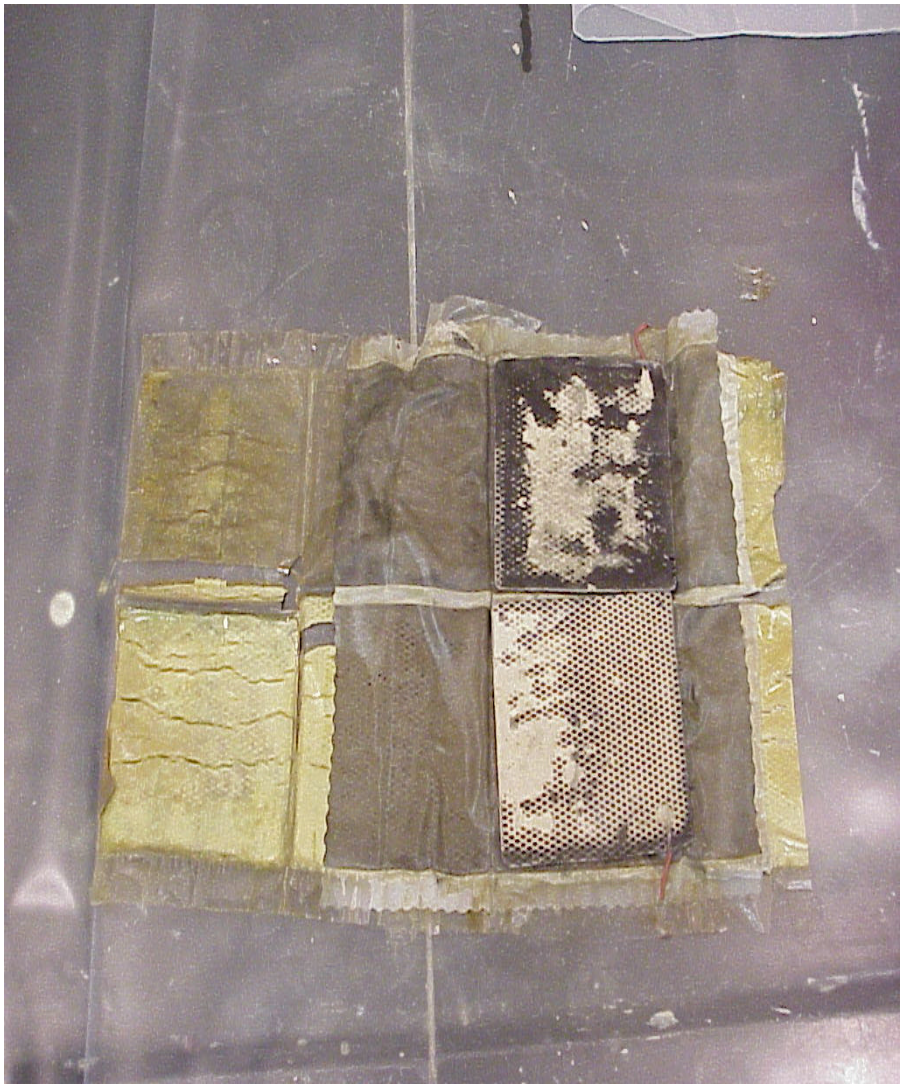
EMU Battery Cell Diagram





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EMU Battery Anomaly

- **STS-112 / 9A and Subsequent Acceptance Rationale**
  - Four (4) newly processed EMU batteries being brought to ISS on STS-112/9A and left behind for increment stage.
    - All EMU batteries on ISS are being brought back on STS-112/9A
    - All EMU batteries will support Shuttle contingency EVA operations
  - All increment batteries will be maintained per summit recommendations
    - Stowed discharged for long dormant periods greater than 50 days
    - Cycled every 85 days to retard / control crystal growth
    - Charge continuously (no interrupted charging) when required for EVA support

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Pistol Grip Tool Low Torque

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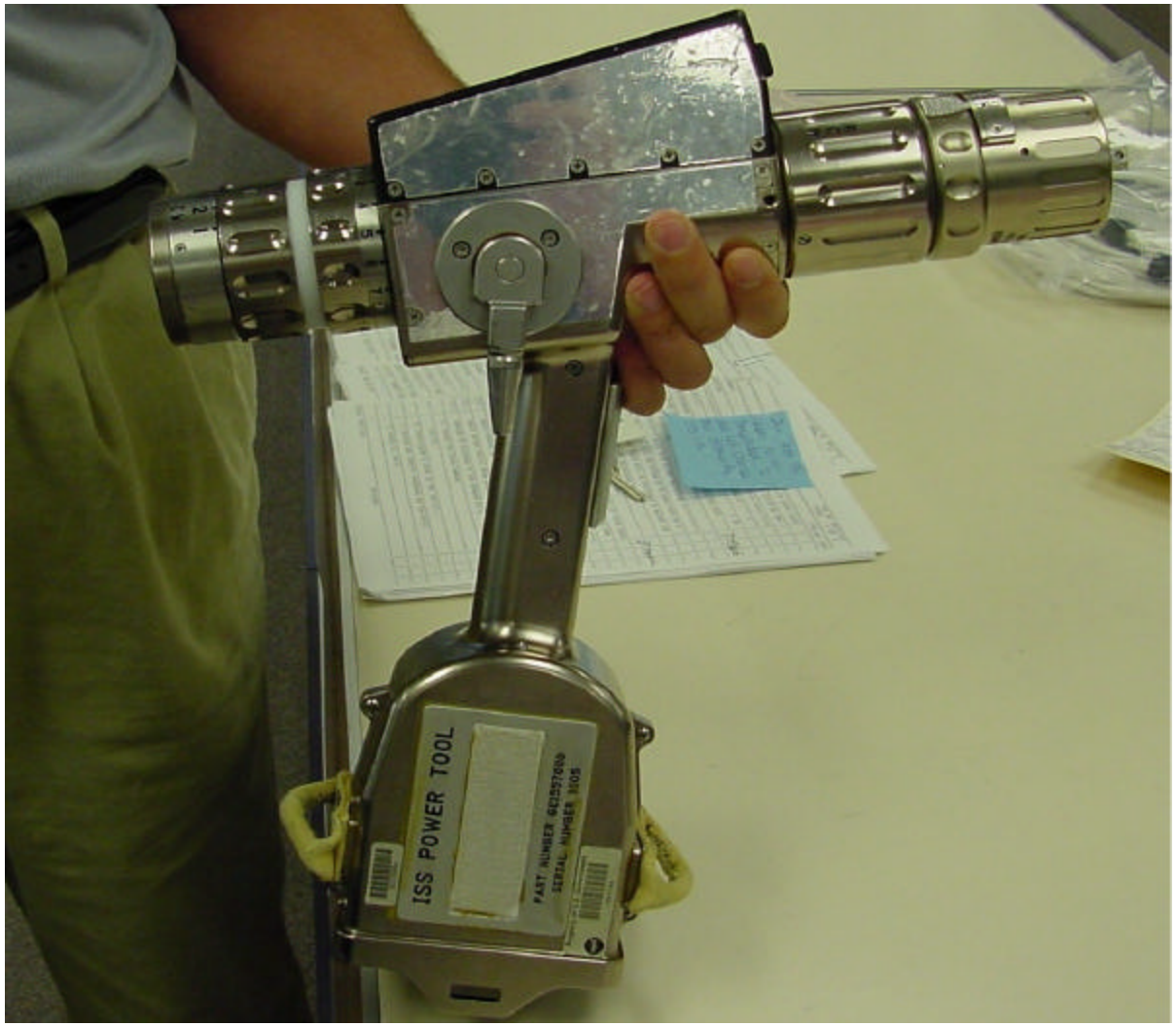
PGT-Low Torque



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STS-112/9A PGT Issues

- **Background**
  - Pistol Grip Tool (PGT) S/N 1007 was found to be out-of-spec for low torque during post UF-2 flight testing
  - Review of historical data shows S/N 1007 has always tested near bottom of specification band compared to remainder of fleet
    #1007 is historically the lowest performer of the tools
    (Spec: ± 1.0 ft-lb below 10 ft-lb and ± 10 % above 10 ft-lb)

    S/N 1007 post-flight test results are not significantly out of family for this tool
  - Subsequent testing resulted in verifying out-of-spec conditions on two independent test stands but at lower frequency and magnitude (~.5 ft.- lbs. out of limits, with one data point at .69 ft.-lbs. out of limits)

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STS-112/9A PGT Issues

- **Background (cont'd)**
  - Although S/N 1007 is the first tool to fail at a pre or post flight test (PIA), Tiger Team assessment is that pass-fail criterion of the PGT is challenging (i.e., approaching the capabilities of the tool). This is an inherent design characteristic due to initial calibration data (data shows scatter) being manipulated using a "best line fit" approach.
  - PGT Fleet (eight flight units) amassing over 3000 data points from pre and post flight tests has never experienced an out of spec condition until the 1007 event.
  - Additionally, four engineering units amassing approximately 500 data points without out-of-spec condition
    - S/N 1007 testing and tear down results showed no obvious off nominal conditions (comparable to initial assembly)

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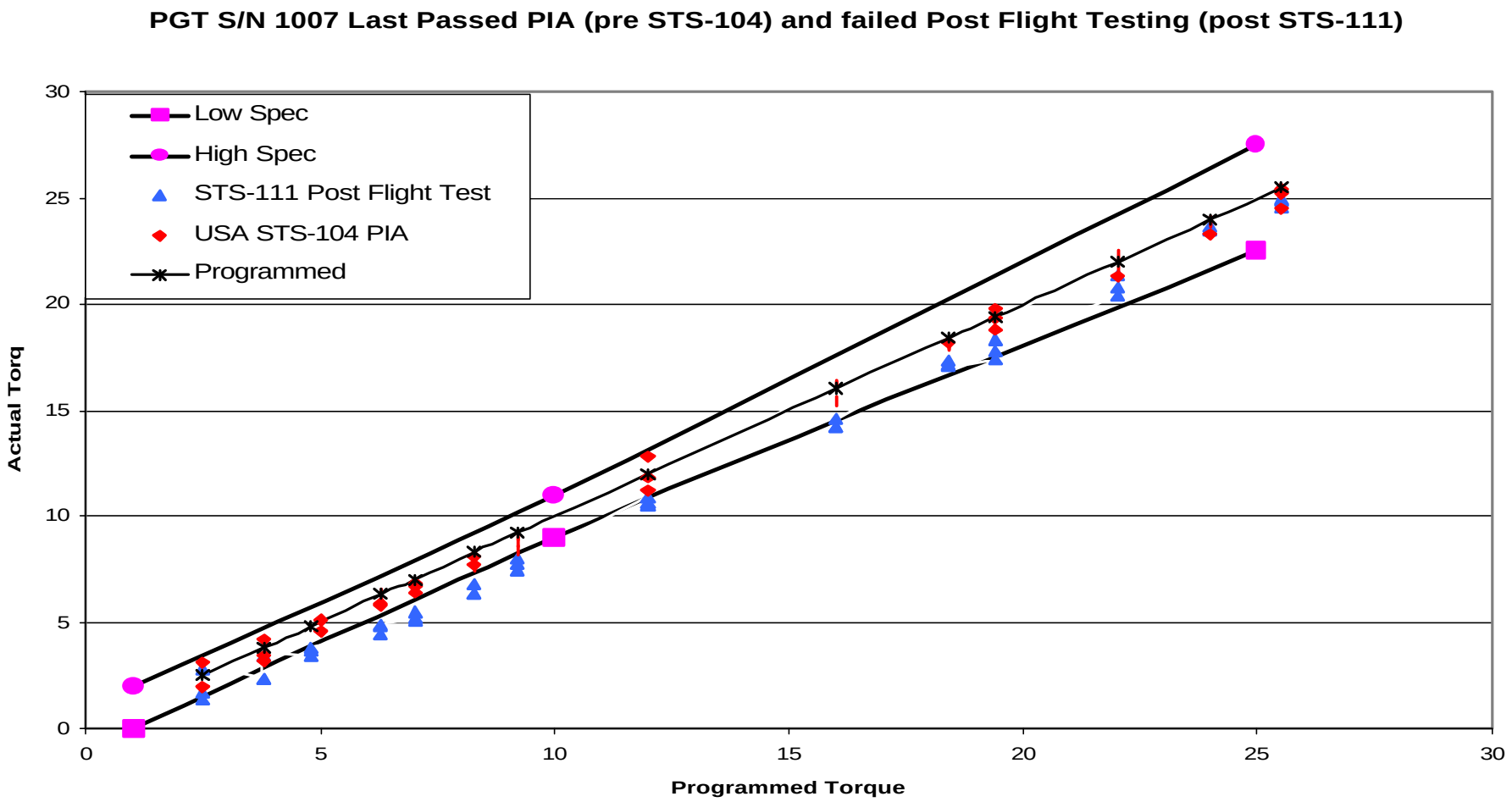
Serial 1007 Performance



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STS-112/9A PGT Issues

- **Background (cont'd)**
  - Since anomaly root cause has yet to be determined, a conservative approach for clearing 9A usage has been taken
    - Conservatism adds confidence because:
      - We have assumed all tools perform at S/N 1007 levels, even though test data on all other units do not indicate any shifts
      - All other units are calibrated at the mid-point or high-end of the spec.
      - We use the worst case performance of S/N 1007 (Average torque -0.5 ft-lb, -1.0 ft-lb worst case data point) as the performance for all other units
      - Out of 3000 data points of performance verification only the S/N 1007 data is out-of-spec
  - In order to ensure PGT anomaly could be "bracketed," a more conservative "knockdown" approach was determined appropriate
    - PGT spec
      - ± 1 ft-lb for torque setting up to 10 ft-lb
      - ± 10 percent for torque settings over 10 ft-lb
    - "Knockdown"
      - - 2 ft-lb for torque settings from 4, 5, to 10 ft-lb
      - - 18 percent for torque settings over 10 ft-lb

What we may have on-orbit

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STS-112/9A PGT Issues

- **Background (cont'd)**
  - "Knockdown" assumes that S/N 1007 produced on-orbit EVA torques equal to the lowest torques experienced in the post UF2, ambient PIA's
    - PGT accuracy/temp sensitivity: Vendor assessment = insensitive
    - PGT accurance / radiation sensitivity: Insight available to upset events (check-sum error competitors)
    - Lowest out-of-spec torques values used to define enveloping threshold, i.e., some discreet torque values less than 10 ft-lb were better than - 2 ft-lb, some greater than 10 ft-lb better than -18 percent

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STS-112 / 9A PGT (Tool Specific) Issues

- **Issues**
  - ISS structure assembled with PGT's, although potentially fine, must be analyzed to assess structural/safety margins. To be addressed by G. Gafka/Engineering Directorate.
  - Existing on-orbit PGT's although potentially fine, must be swapped with ground units to remove any additional questions for PGT torques. See conclusions.

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Flight 9A Special Topic
PGT Torque Issue / Vehicle Impact

- **Background / Assumptions (from a vehicle impact perspective)**
  - –Pistol Grip Tool (PGT) Tiger Team assumption is that previous on-orbit PGT performance (torque behavior) is validated by standard ground test, Pre-Installation Acceptance (PIA) when PGT is returned post-flight
    - With discovery of an out-of-spec condition, only need to look back to last known “good” PIA data
    - Results to date from root cause investigation support assumption
  - –Several recent PIA tests conducted on S/N 1007 as part of the root cause investigation
    - Lowest out-of-spec PIA results on S/N 1007 used to develop PGT performance “knockdown” for backward-looking (currently on-orbit) and forward-looking (Flight 9A) structural assessments
  - –On-orbit PGT usage by S/N is not always tracked
    - S/N 1007 performance “knockdown” applied to other locations where bolts were torqued (or are to be torqued) with suspect PGT
      - –Suspect PGT = a PGT that has not yet returned/PIA (any currently on-orbit PGT)

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Flight 9A Special Topic
PGT Torque Issue / Vehicle Impact

- **Issue Scope: affected locations**
  - –PGT S/N 1007 was returned from orbit post-UF2 and found to be out-of-spec, *8/06/2002*
    - **Currently on-orbit:** Last time PGT S/N 1007 was known to be "good" via ground test was pre-7A, *5/02/2001*, S/N 1007 not used on UF-2
      - –Concern: All PGT S/N 1007 use between 7A and 8A, assume S/N 1007 performance "knockdown" at these locations
    - **Currently on-orbit:** Last time current on-orbit PGTs (S/N 1004, S/N 1006, S/N 1008) were known to be "good" was pre-7A, either by pre-7A ground test or by the fact that we know they were not used on-orbit before 7A
      - –Concern: All PGT's S/N 1004, S/N 1006, S/N 1008 use between 7A and UF-2, assume S/N 1007 performance "knockdown" at these locations
    - **Flight 9A:** Current lack of full root cause determination for anomalous test results
      - –Concern: Which PGTs we will use on 9A and how we will verify proper torque? Assume S/N 1007 performance "knockdown" at all 9A locations
  - –**Conclusion: Assume PGT S/N 1007 performance "knockdown" at all PGT work-sites from 7A through 9A to clear both the on-orbit vehicle and Flight 9A**
    - Performance "knockdown" magnitude is not gross, but breaks the lower torque bound established to preclude joint gapping in some places

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Flight 9A Special Topic
PGT Torque Issue / Vehicle Impact

- Resolution: On-Orbit
  - **S/N 1007 performance "knockdown" for all PGT work-sites on Flight 7A through Flight UF-2 (backward-looking assessment)**
    - Struct&Mech community conducted an assessment for all suspect PGT locations to quantify joint robustness in the face of possible initial under-torque (under-preload)
    - Flight 8A contained several assembly tasks which utilized on-orbit PGT's (including S/N 1007) for bolt torque (joint preload)
      - ISS critical structural interface: MTS adjustable strut provides permanent structural attachment of the S0 truss element to the US Lab
      - If MTS strut bolts were under-torqued per S/N 1007 "knockdown", then MTS interface has not suffered loads to date that would have compromised on-orbit vehicle integrity (I.e. UF-2 loads)
      - Furthermore, structural assessment results in no unfavorable MTS loading events **through 11A stage**
    - All other PGT uses from Flight 7A through UF-2 have been analytically dispositional in a similar manner
      - Assuming S/N 1007 "knockdown", no damage from initial time of torquing to today
      - No unfavorable load events **through 11A stage**
      - FRR Charts created assuming some amount of open work completion, verify real-time

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Flight 9A Special Topic
PGT Torque Issue / Vehicle Impact

- **Resolution: Flight 9A**
  - **S/N 1007 performance "knockdown" for all PGT work-sites on Flight 9A due to current PGT uncertainty (forward-looking assessment)**
    - Struct&Mech community conducted an assessment for all suspect PGT locations to quantify joint robustness in the face of possible initial under-torque (under-preload)
    - All other PGT uses on Flight 9A have been analytically dispositioned in a similar manner as before
      - Assuming S/N 1007 "knockdown", no damage / unfavorable load events from initial time of torquing **through 11A stage**
      - FRR Charts created assuming some amount of open work completion, verify real-time
  - **Risk assessment: (low/medium/high)**
    - Low for currently on-orbit and Flight 9A hardware, through stage 11A
      - Further risk mitigation required to fully disposition current issue scope post 11A stage
      - Further risk mitigation required to disposition Flight 11A (and beyond) hardware
  - **Acceptable for flight: (yes/no)**
    - Yes
  - **Status: (open/closed)**
    - Concern closed for Flight 9A, technical concurrence: PGT Tiger Team, S&M SPRT, Vehicle
    - Formally open for final disposition per ISS Program IFI / PRACA process
      - Currently open IFI 893 will be closed and rolled into ISS PRACA with Flight 9A effectively and dispositioned to support Flight 9A, concurrence: PGT Tiger Team, S&M SPRT, Vehicle, MER

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STS-112 / 9A PGT Issue

- **Forward Work**
  - Complete Tiger Team investigation
    - Identify root cause (if possible)
      - Leading candidate for root cause is that multiple small contributors are combining and causing anomaly
        - » Procedural test set-up error inducing an offset – potential of up to 0.7 ft-lb offset could be induced
        - » Tool variability
        - » Slight power train shift (mechanical wear)
        - » Slight test stand shift (computer / display component and / or transducer component)
    - Complete program acceptance of fault tolerance waiver and newly identified CIL. ECD 9/20/02
      - Examination of hazard controls discovered discrepancy in fault controls (Tiger Team significant other finding) zero fault tolerant to torque detection
    - Complete near-term logistics plan for 9A and subsequent flights. ECD 9/20/02
    - Implement appropriate corrective actions

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STS-112 / 9A PGT Issue (cont.)

- **Conclusion**
  - STS-112/9A acceptance rationale
    - Interim failure closure
      - Two recently verified PGT's utilizing both independent test stands are being delivered to ISS on STS-112 / 9A returning all on board units for further evaluation (calibration check)
      - No other anomalous conditions have ever been reported during tools first use post calibration verification (sample size of 20+ flights with confidence factor of over 3000 data points with the exception of S/N 1007
      - PGT design is extremely robust in single string components
        - » Highly reliable mill grade space qualified resistors makeup the wheat stone bridge (torque transducer)
        - » Credible failure modes for these components are screenable during PIA and on-orbit and have not been seen in history of PGT
      - All STS-112 / 9A PGT uses (ISS bolts) have been analyzed for the worst case S/N1007 knockdown condition and found acceptable by the Structures and Mechanism Tiger Team representatives

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STS-112 / 9 A FRR Planned Forward Work

	Title	Definition	Org	Due Date	Risk
PFW	Resolve PGT – low torque issue	• Obtain programmatic acceptance of PGT documents – Open failure – Fault tolerance waiver – CIL acceptance	XA	NLT 9/26/02	Low
PFW	0.5” SPD open certification	• New hardware certification. Late identified requirement.	XA	9/20/02	Low

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STS-112 / 9A FRR

- **There are three EVA exceptions for STS-112/9A**
  - Open failure
  - Fault tolerance waiver
  - CIL acceptance
- **The EVA Project Office is ready to proceed with the launch of STS-112/9A pending closure of exceptions and completion of planned forward work**
- **All STS-112/9A open work will be closed or dispositioned by L-2**

Original signed by:

G. Allen Flynt

Manager, EVA Project Office

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STS-112 / 9A
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Backup Charts

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Backup Charts

- **EVA Tools and Crew Aids Being Swapped**
  - EMU
    - X-Large EMU (up) and Medium EMU (down)
    - Four increased capacity battery (up) and five (down)
  - SAFER's:
    - S/N 1004 (up) and S/N 1005 (down)
  - Retractable Equipment Tethers (2)
- **EVA Tools and Crew Aids being Transferred**
  - CETA Cart (1)
  - EVA Tether Shuttles (2)
  - 0.5" (2), 1.0" (28), and 1.5" (13) SPD's
  - 0.25" (1) , 0.5" (2), and 1.0" (1) QD cap removal tools
  - Fluid QD tool bag (1)
  - 1.0" and 1.5" QD Release Tool w/FID gauge (2 each)
  - 1.5" QD bail drive lever tool (2 each)
  - Small QD bail lever (2)
  - Gap Spanner (6)
    - 2 each: 18-21", 21-30", and 45-72"
  - ORU Transfer Bag

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Backup Charts

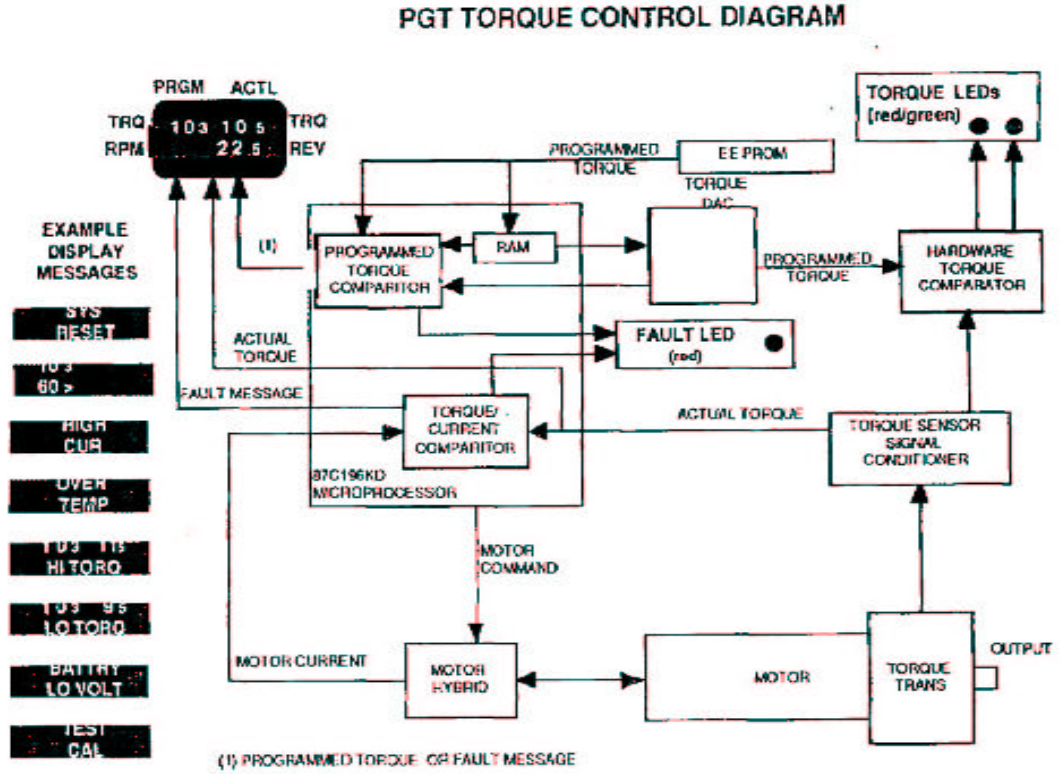

Figure 1-1

HST SM2 NCR 42

U.S. Gov't

ATTACHMENT 1-3

Gpl3

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