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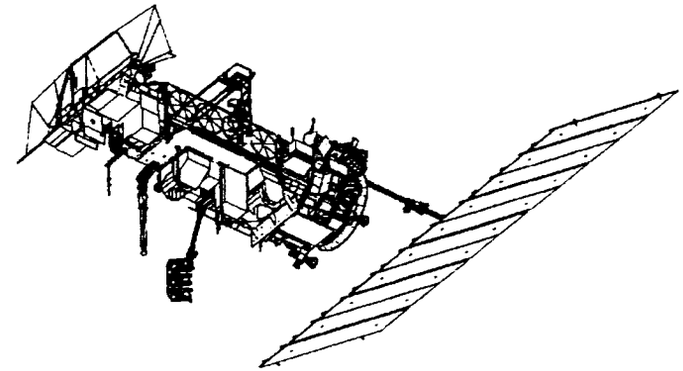
NOAA-L External Independent Readiness Review

Summary Briefing

July 13, 2000

Allen Goldstein



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THE AEROSPACE CORPORATION
El Segundo, California

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NOAA-L External Independent Readiness Review

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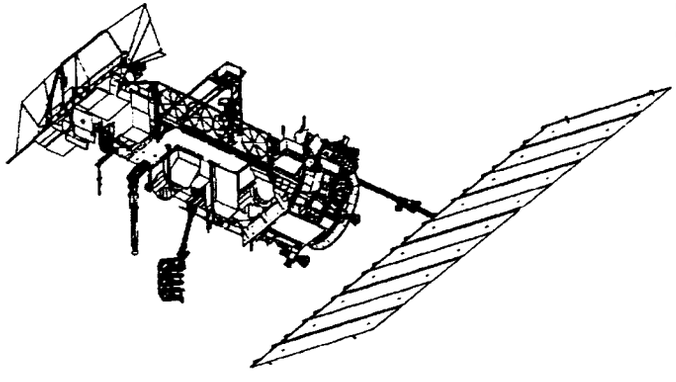

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EIRR Briefing Outline

- Background
- Principal Observations/Findings
- Panel Findings
  - / Spacecraft & Instruments
  - / Launch Vehicle Interfaces/Integration
  - / Mission Operations
- Summary & Recommendations

NOAA-L EIRR Charter

- Independently assess NOAA-L mission state-of-readiness and launch risk
  - / Spacecraft
  - / Sensors (AVHRR and HIRS)
  - / Mission operations
  - / Launch vehicle integration

- Identify areas of risk and recommend mitigation actions

NOAA-L EIRR Scope

- All major components/subsystems with emphasis on first flight items
- Mission design changes including software
- Disposition of related problems/anomalies on similar hardware
- Acceptability of major discrepancies and non-conformances
- Resolution of flight and unconfirmed ground anomalies
- Changes to mission operations
- Open items/paper from East Windsor for proper closeout
- Launch vehicle mating and interfaces

NOAA-L EIRR Team Composition

Review Leader

Allen Goldstein

Spacecraft/ Instruments

Rick Seebach

- Robert Tsutsui
- Peter Chang
- Frank DeLuccia
- Brian Gore
- Don Nelson
- Julio Rivera

Launch Vehicle & Integration

Gary Mueller

- Chester Orciuch

Mission Operations

George Iwanaga

- Peter Phillips
- Richard Debor

NOAA-L EIRR Chronology

- Team formed May 99
- Spacecraft Panel meeting with LMSS 4 Aug 99 (51 RFAs)
- Instrument topics review at ITT 17 Sep 99
- Periodic telecons/meetings to review RFA data/responses
- Attended several Program Review meetings (8 RFAs)
- Mission Ops Panel meeting with NASA/NOAA 17 Feb 00 (9 RFAs)
- Participated in Pre-Ship Review 28 Feb 00
- Prepared preliminary assessments/findings/recommendations
- Provided draft report to Red Team 19 May 00
- Launch Vehicle Panel meeting with KSC/AF 24 May 00
- Additional discussions to refine findings/recommendations
- Report to GSFC Management Council 13 July 00

NOAA-L EIRR
Principal Observations

- Repeat of largely successful NOAA-K (15) mission
  - / Should provide similar or better performance than K
  - / Quality trends are positive
  - / Improvements made to avoid repeat of NOAA-K anomalies
  - / All first flight items assessed as low risk
- S-band transmitter and HIRS FW issues have been resolved
- Proven ground systems and mission ops processes
  - / Largely heritage procedures and contingency plans
  - / New ops support contractor - experience/training concern
- Titan II launch performance and reliability have been very good
  - / Proven interfaces and environments
  - / Mission assurance has been enhanced
  - / Fixes implemented for G-8 Stage 2 LRE anomaly

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Spacecraft Panel
Special Emphasis Items

- Major design/vendor changes K to L (first flight items)
- Changes in manufacturing, integration and test flows
- Acceptability of major discrepancies and non-conformances
- Acceptability of cannot duplicate test observances
- Disposition of NOAA-K EIRR recommendations/concerns
- NOAA-K on-orbit performance and anomalies
- Quality trends
- Generic problem parts (Vishay Resistors, etc.)
- Flight software changes
- Closeout of "old paper and issues" from East Windsor
- Changes in mission design or early on-orbit checkout
- Revisions to launch base flow and testing

AVHRR and HIRS Sensor Review Topics

- Manufacturing and test flow
  - Test approach, procedures and milestone history
  - Deviations from NOAA-K
- Changes relative to NOAA-K instruments
- NOAA-K instrument on-orbit performance
  - Changes from pre-launch test results
- Generic parts problems (on any program)
- Sensor related UVFs and ATP type anomalies
- Sensor test data/results
  - Acceptance tests
  - Anomaly disposition

Significant Design Changes
NOAA-K to L

- SBUV/2 not flown on NOAA-K
- Spectrolab solar cell interconnect replaces LMSS in-house process
- Solar array pyro rewire to provide redundancy for battery failure
- Battery complement changed to three lighter weight 40 A hr
- Battery heater size increased to provide greater duty cycle margin for cold orbit
  - / Correction due to NOAA-15 on-orbit heater performance
- Wire harness routings and thermal blanket closeouts modified to address NOAA-K on-orbit deployment anomalies
- On-orbit flight software updated and acent guidance mission constants changed

All changes adequately verified - low risk

Disposition of NOAA-K EIRR Concerns/Recommendations

K EIRR Recommendation	NASA Response	L EIRR Disposition
<u>Unresolved Open</u> Validate flight worthiness of two out-of-date N_2H_4 subsystem pyro valves	Analysis testing shows O-ring material does not age appreciably and will not affect operation of pyro valves.	Close - Pyro valves worked on NOAA-K. Not a concern on NOAA-L.
Verify safe SV/booster separation for condition of failed V-band release pyro.	Conservative independent analysis shows positive margin for this failure scenario.	Close - Good booster/NOAA-K separation.
<u>Residual concerns - Low Risk</u> Conduct additional tests to understand cause of DAU occasionally sticking in encrypt mode during AGS.	Command encryption worked in all end-to-end tests and problem has not repeated. DAU consistently responds to manual commands. Encryption not essential to mission success.	Close - DAU functioning well on NOAA-K and problem has not occurred on NOAA-L.
Assure no mission threatening RCE leaks on NOAA-K.	NOAA-K RCE passed all high and low pressure leak tests with acceptable results.	Close - No evidence of RCE leakage (excessive thruster action or N_2H_4 use) on NOAA-K. RCE fittings changed out on NOAA-L&M
Replace resistors from lot in which several cracked units were found.	Only one failure attributable to this problem and was caught in test. Accept contractor use as is recommendation.	Close - No additional occurrences on NOAA-K or NOAA-L.

NOAA-L Can Not Duplicate Test Items

Item	Most Probable Cause	Potential Impact
ADR-103644: Memory error in CPU S/N 3 during abbreviated test in 7th thermal cycle.	STE noise spike.	Loss of redundancy
ADR-112148: DAU input current on 28V side 2 >100ma during power cycling. Short found at U49.	U49 part OK in failure analysis. Suspect initial power-on condition not set properly.	Loss of redundancy
ADR-139177: pattern mismatch in CIU buffer 22A (through SCP2) in thermal cycle 4th hot plateau. No mismatch in prior or subsequent tests.	MATS noise glitch	Loss of redundancy
ADR-K 1049: Error during memory test of CPU-1 (GALPAT). CPU-2 portion of GALPAT test successful.	Not determined. Memory dump not made when problem occurred and failure has not repeated in subsequent testing.	Loss of redundancy. Decision to fly this CPU (S/N 3) IN CPU-1 position only.

NOAA-L Can Not Duplicate Test Items (Cont.)

Item	Most Probable Cause	Potential Impact
ADR-K1041/K1137 - During TP-SOF the AVHRR S/N 301 cooler door opened and AVHRR Channel 4 was enabled. No Cmd sent to CIU (S/N 2)	Not determined. No pulses observed in either command line during AVHRR 302 IPF, and subsequent testing with CIU S/N 2 and AVHRR 301.	Degradation of Channel 4 detector sensitivity
ADR-K1136. CIU S/N 2 responded with single and double bit parity errors via CV telemetry during ATNAGE procedure to lock-up ground for commanding.	Not determined	Random generation of invalid commands. SOCC assessed as minor effect on mission

All CND Items Acceptable - Low Risk

Spacecraft and Sensor Panel
Partial List of Topics Covered

- TIROS-15 SBA anomalies
- + S-Band transmitter flight worthiness
- * S-Band transmitter TRAK oscillator
- * Deployment system margins/redundancies
- + Final mechanical closeout inspection
- * Pyro devices shelf life
- PSE mode switch anomaly
- TIROS-15 gyro bias shift
- * TIROS-15 HIRS filter wheel current
- AMSU-B EMI compatibility
- + Pin-wheel louver torque test
- Problem piece parts
- Unfused power system loads
- + Responsible eng. experience level
- NOAA-K AKM underperformance
- + Solar array workmanship
- SADPOS software
- + Weight and balance test limits
- * FMEA and SPF list
- Component test level adequacy
- Flight software validation
- + RCE heaters
- Thermal model correlation
- + Battery t-stat redundancy check
- RCE tubing leaks
- 5 volt bus loading

→ Recommendations Open + Recommendations Implemented * Future Improvements

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S-Band Transmitter TRAK Oscillator

Background

- DMSP S-band transmitter failed output power requirements during post-rework testing
- Failure traced to TRAK oscillator becoming detuned
  - / Anoamlies found in two additional transmitters
- Oscillator examination and in-situ x-rays revealed several suspect areas
- Capacitor supplier expressed concern for axial loading in TRAK design
  - / DPAs verified stress induced solder cracks

EIRR Assessment

- Failed unit passed earlier transmitter acceptance tests
- Oscillator circuit parameters appear to have changed with time/cycles
- Transmitter level testing not perceptive screen since 3dB to 5dB shift in oscillator output needed before detectable change in transmitter output
- X-ray alone is not effective screen since viewing angles are limited
- DMSP planning oscillator level measurement to screen for "best" unit

S-Band Transmitter TRAK Oscillator (Cont.)

EIRR Assessment (Cont.)

- TIROS risk mitigated by high level of redundancy
  - One of four transmitters required for mission data
- Mission risk of transmitter removal and replacement on NOAA-L probably greater than to "fly as is"

Recommendation (For M and On)

- Utilize results of DMSP oscillator level screening to reassess adequacy of transmitter acceptance test and unit selection
- Consider oscillator rebuild or redesign to eliminate known defects

HIRS High Filter Wheel Current

Background

- High filter wheel current noted on NOAA-15 (ref. TOAR 377 & 384)
  - Spikes of 50% increase in current seen since Nov. '99
  - Motor and housing temperatures increased with similar trends
- Problem worsened in June with some degradation in data quality
- FW has recovered to normal

EIRR Assessment

- NASA and ITT postulating increased drag torque in bearings
  - Likely caused by buildup of debris (degraded lubricant and/or retainer wear)
- HIRS on NOAA-L and -M have same bearing and lube system
  - No indication of bearing problem in life test or other units
- NOAA-K FW exhibited higher jitter and chirp in ground tests than seen in NOAA-L or life test units

Recommendation

- Continue to monitor NOAA-15 FW for new symptoms
- Compare NOAA-M FW build and test data with that of NOAA-K

Responsible Engineer Experience Level

Background

- Examined TIROS program and total space experience levels of PIE/RPE's for all major NOAA-L boxes

EIRR Assessment

- LMSS engineering knowledge and experience base for TIROS and DMSP programs significantly weakened by transition to Sunnyvale
- Many competent individuals, but very low experience base and heritage knowledge of program
- Participation in simulations/rehearsals and training on COPs being enhanced per EIRR Team recommendation

Recommendation

- Implement retention program to maintain skills and knowledge base needed to successfully complete NOAA ATN program
  - Consider cross training and sharing of RPEs with DMSP

Spacecraft Panel Principal Findings

- NOAA-L spacecraft quality trends show improvement over -K
  - Minor concern over pre-ship SEPET problems
- First flight items are low risk improvements
  - All have been adequately tested and verified
- Investigation of NOAA-15 SDA and deployment mechanism anomalies have been thorough
  - Agree with most probable causes and corrective actions
- S-band transmitter TRAK oscillator and HIRS FW issues resolved
  - Acceptably low mission risk to "fly as is" for NOAA-L
- Fully expect NOAA-L to meet 2 year design life and 3 year goal
- Loss observed in heritage program knowledge and experience base -- Concern with trend

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Launch Vehicle & Integration Panel Special Emphasis Items

- First flight items
- LV/SV interfaces
- Major LV field modifications
- Significant LV problems and anomalies
- Booster/SV separation
- Verification process

Titan II G-13 First Flight Items

- Flight Vehicle
  - / Herley-Vega C-band transponder (was Motorola)
  - / Automated wire harness continuity/isolation checks
  - / New configuration accelerometers at SV interface
  - / G-8 Stage 2 LRE anomaly corrective actions
    - – Turbine seal and replacement with TIV unit
    - – Redesigned lube oil filter screen and sump tube
  - / New engine transducers installed (PLD/PGGB)

- Ground Equipment
  - / Minor PACE modifications
  - / New P/L fairing air conditioning control system
  - / Environmental enclosure door actuators reworked
  - / MST sliding doors removed (Level 1-16)

Launch Vehicle and Integration
Partial List of Topics Covered

+ • Titan G-8 Stage 2 engine anomaly
- • ACS bladder overpressure
- • Actuator back EMF
+ • Cracked engine frame rivets
- • Connector pin retention test
- • V-band clamps
- • SV - Booster separation analysis
- • NOAA-K IMU environment
- • Titan II performance and accuracy
- • SV interfaces and environments

→ Recommendation open

+ Recommendation being implemented

Titan G-8 Stage 2 Engine Anomaly

Background

- Engine experienced drop in lube oil discharge pressure from 40 to 28 psi at ~T + 246 sec
- Turbine speed and engine thrust degraded 8-10% at ~T+ 263 sec
- Lube oil pressure recovers and rises to 77 psi max and then decayed
- Engine thrust returned to ~ normal at T+ 284 sec

EIRR Assessment

- Extensive fishbone analysis and investigation conducted
- Three major scenarios identified as possible causes
- Most likely caused by filter screen blockage in lube oil reservoir due to products generated by reaction of turbine gas pressurant with oil
  - Turbine seal leakage allows added flow of turbine gas into oil reservoir

Titan G-8 Stage II Engine Anomaly (Cont.)

EIRR Assessment (Cont.)

- Planned corrective actions
  - / Replace turbine seal with a TIV configured seal
  - / Redesign lube oil filter to increase "dirt capacity"
  - / Lengthen sump lube oil suction tube
  - / Verify engine/lube system bolt torques and lockwire installation
  - / Enhance lube system flush, fill and oil sample processes
- Tests of new lube oil filter design in progress
  - / Schedule aggressive - CDR 16 June; Qual complete 17 July
  - / Gear box level qual planned with three filters
  - / Demonstrate in single TPA test
- Use of TIV turbine seal as a drop-in replacement was previously qualified by TPA tests in 1965
  - / Rationale for qual by test and similarity revalidated
  - / Plan to demonstrate seal in filter TPA test

Recommendation

- Fully qualify new lube oil filter and sump suction tube, and implement other identified corrective actions
- Consider hot fire test of modified design to more fully "test as you fly"

Launch Vehicle and Integration Principal Findings

- Titan II G-13 quality within family of recent vehicles
- Performance margins are adequate
- No significant changes to interfaces or environments
- NASA KSC/Air Force Mission Assurance process is very good
- G-8 stage 2 LRE anomaly is understood and appropriate corrective actions are being implemented
  - / Turbine seal replacement previously qualified by TPA test and analysis
  - / Qualification of new lube oil filter and suction tube planned at gear box level with turbopump level demonstration test
- Other first flight items are low risk

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Mission Operations Panel Review/Special Emphasis Items

- Significant changes from NOAA-K
- Recent operational/on-orbit problems
- Mission control team readiness
- NOAA operations readiness
- Flight software problems
- Ground systems status/readiness

Significant Changes Between NOAA K&L

- First KLM spacecraft with SBUV sensor
- Hardware changes to address NOAA-K problems
- Flight software re-mapping and upgrades
- New 13M antennas at NOAA CDAs
- New GDP polar frame synchronizers
- Relocated launch control room (LCR)
- QSS replaced Boeing as NASA/POES Technical Support Contractor

Mission Operations
Partial List of Topics Covered

- + • Flight S/W project assurance
- + • Contingency procedure robustness
- → • Test and checkout completeness
- + • Ground systems readiness
- + • Command verification
- * • Flight S/W macro load generation
- + • Operations team readiness
- • TOAR closeout
- • Ground system testing and anomalies
- • Launch-to-orbit tracking support
- • Mission operations schedule
- • Training and simulation plans

→ Recommendations Open + Recommendations Implemented * Future Improvements

Contingency Procedure Robustness

Background

- Audited contingency operations procedures (COPs) for completeness and thoroughness

Assessment

- NASA-authored COPs are comprehensive
  - Cover all plausible on-orbit failure modes
- Most COPs require engineering presence to accomplish
- NOAA operations crews have no stand-alone procedures to safe the spacecraft without engineers present
  - Engineers for 10 days on -L vs 60 days for -K
- Concern over possibility of delayed corrective action in time-critical emergency

Recommendations - Being Implemented

- Develop a reduced set of COPs for NOAA ops personnel use in those situations requiring immediate response to protect spacecraft and/or instruments
- Train NOAA on-duty operations personnel on identifying entry conditions and running the reduced set of COPs

Operations Team Readiness

Background
- Reviewed operations team staffing, experience and training
- Rehearsals/training not observed by EIRR

Assessment
- Many LMSS, QSS, NOAA personnel new to POES program since NOAA-K launch
- NOAA engineering support contractor changes before launch
  / Concern over availability of highly experienced personnel for OV
- POPS/XPOPS loading will be practiced during an OV rehearsal as recommended by EIRR
- NASA will document COPs training for new personnel as recommended by EIRR
- Additional rehearsals being implemented as recommended

Recommendation
- Establish comprehensive program to train and "certify" new POES personnel
- Obtain services of previous key technical support personnel for OV phase [NOAA working to implement]

Test and Checkout Completeness

Background

- End-to-End (ETE) and early orbit operations verification test plans and procedures were audited for completeness in checking out all spacecraft systems and ground-to-spacecraft interfaces

Assessment

- ETE and OV test procedures are relatively mature and pre-structured to minimize risk to spacecraft
- Instrument commanding from SOCC not verified at launch base
  - / Problems with SOCC database, etc. must be fixed during OV
- Redundant hardware not checked out on-orbit by OV team
  - / Risk of switching to unproven redundant side must be borne by NOAA if problems occur after satellite is operational

Recommendation

- Review OV philosophy to not test redundancy with NOAA

Mission Operations Principal Findings

- Facilities and ground systems are mission-ready
- NASA/NOAA team functioning well
  - Good process for identifying and resolving issues
- Procedures and contingency plans largely heritage from K
  - NOAA developing abridged COPs for use by ops personnel in time-critical emergencies without engineering presence
- Change in engineering support contractor prior to launch presents a challenge in retaining NOAA-K experienced personnel
  - Recommendations to enhance training and rehearsals being implemented
- Enhancements identified for continued ops risk reduction

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NOAA-L EIRR Summary

- NOAA-L mission state of readiness was assessed over a 10 month period
  - Most issues closed as no concern, low flight risk or recommendations adopted
- NOAA-L spacecraft first flight items are low risk
- Adequate fixes have been implemented and verified for TIROS-15 SBA and deployment system on-orbit anomalies
- S-band transmitter and HIRS FW issues resolved as low mission risk
- NOAA-L mission risk further reduced by:
  - NOAA-K experience and program heritage
  - Repeat integration on T-II booster
- Qual in work for Titan II G-8 LRE anomaly fixes
- Recommendations are made to address remaining minor concerns for NOAA-L mission and for future improvements
- Final SV and LV processing, mission rehearsals and formal reviews are yet to be accomplished

NOAA-L EIRR
Principal Recommendations

+ AUDRR

- Continue to monitor NOAA-15 HIRS FW for new symptoms
- Complete qualification of new lube oil filter design and consider hot fire test
- Reconsider philosophy to not test redundancy in OV phase
- Obtain services of previous key technical support personnel for OV phase

Principal Recommendations for Future Risk Reduction

- Utilize results of DMSP oscillator level screening to reassess adequacy of s-band transmitter acceptance tests
- Evaluate TRAK oscillator rebuild or redesign to eliminate known defects
- Verify adequate force margins for worst case solar array cant deployment to 37 deg
- Update deployment mechanism force margin predictions and consider corrective measure where necessary to meet 100% margin goal
- Develop integrated pyro retest/procurement strategy with DMSP and incorporate MIL-STD-1576 5 yr/10 yr shelf life test requirements into all pyro device specifications and acceptance procedures
- Implement retention program to maintain skills and knowledge base needed to successfully complete NOAA ATN program
- Establish comprehensive program to train and "certify" new POES personnel