

# Thermal Infrared Sensor Scene Select Mirror Encoder Issue

3 Feb 2015

**Jim Lacasse**

USGS, Landsat Operations Project Manager

[jmlacasse@usgs.gov](mailto:jmlacasse@usgs.gov), (605) 594-6140

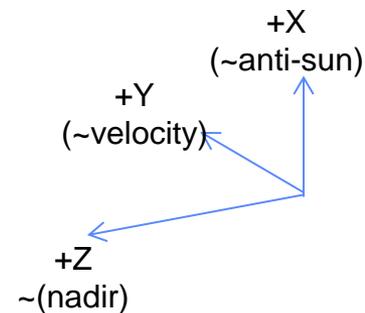
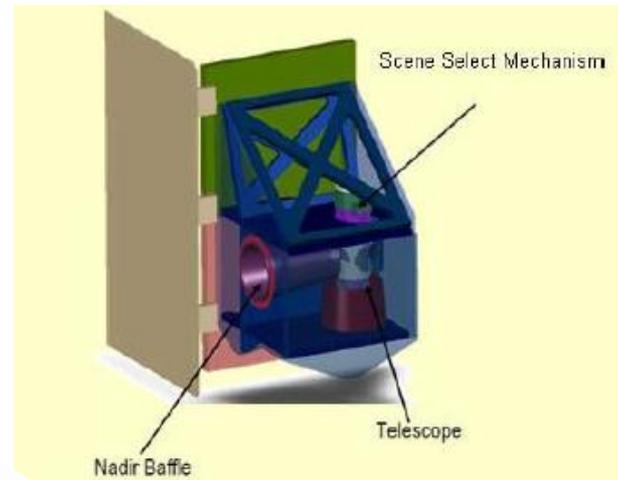
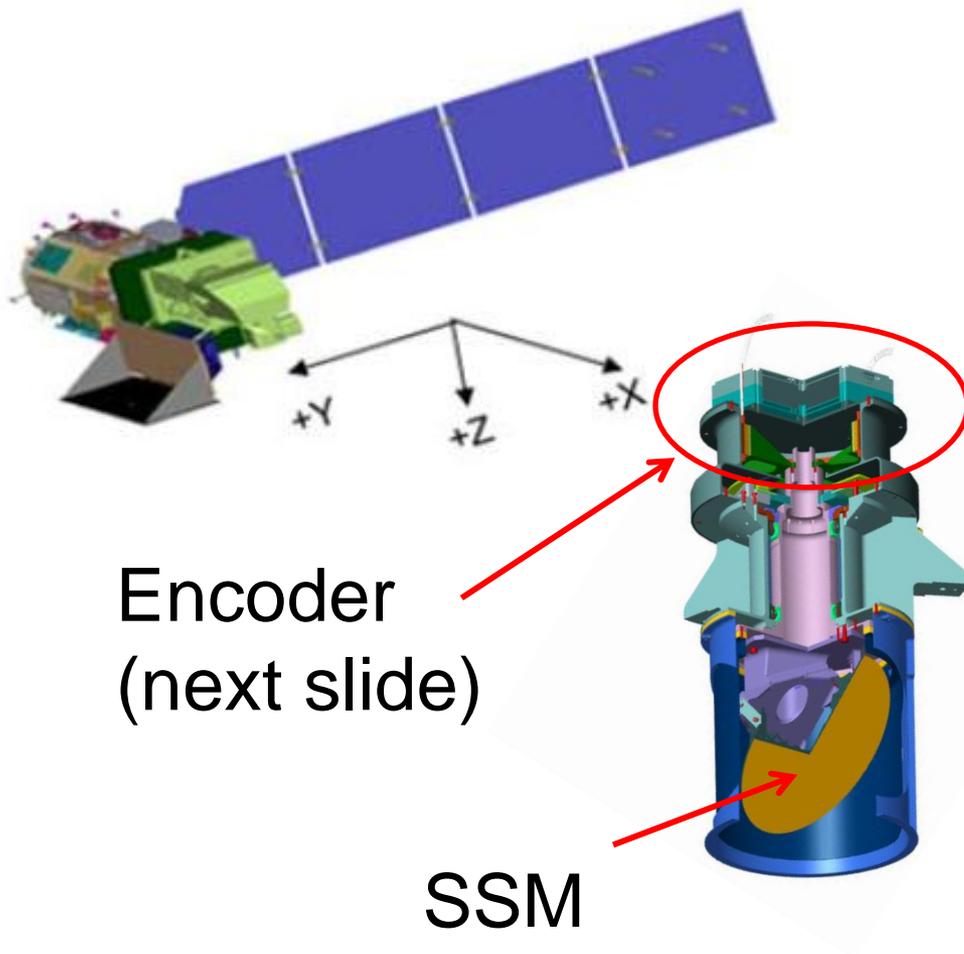
# Background – TIRS SSM

---

- Normal TIRS radiometric calibration collection consists of 2 mission data collect types: one blackbody view and deep space view
- These are collected through the rotation of the Scene Select Mirror (SSM)
- The position of the SSM is provided through an optical encoder and its telemetry included in Mission Data files
- TIRS is normally operated in mode-4, closed loop mode provides precise SSM position control and information for geometric image correction
- Mode-0, open loop mode, provides no SSM position control but can provide SSM position information



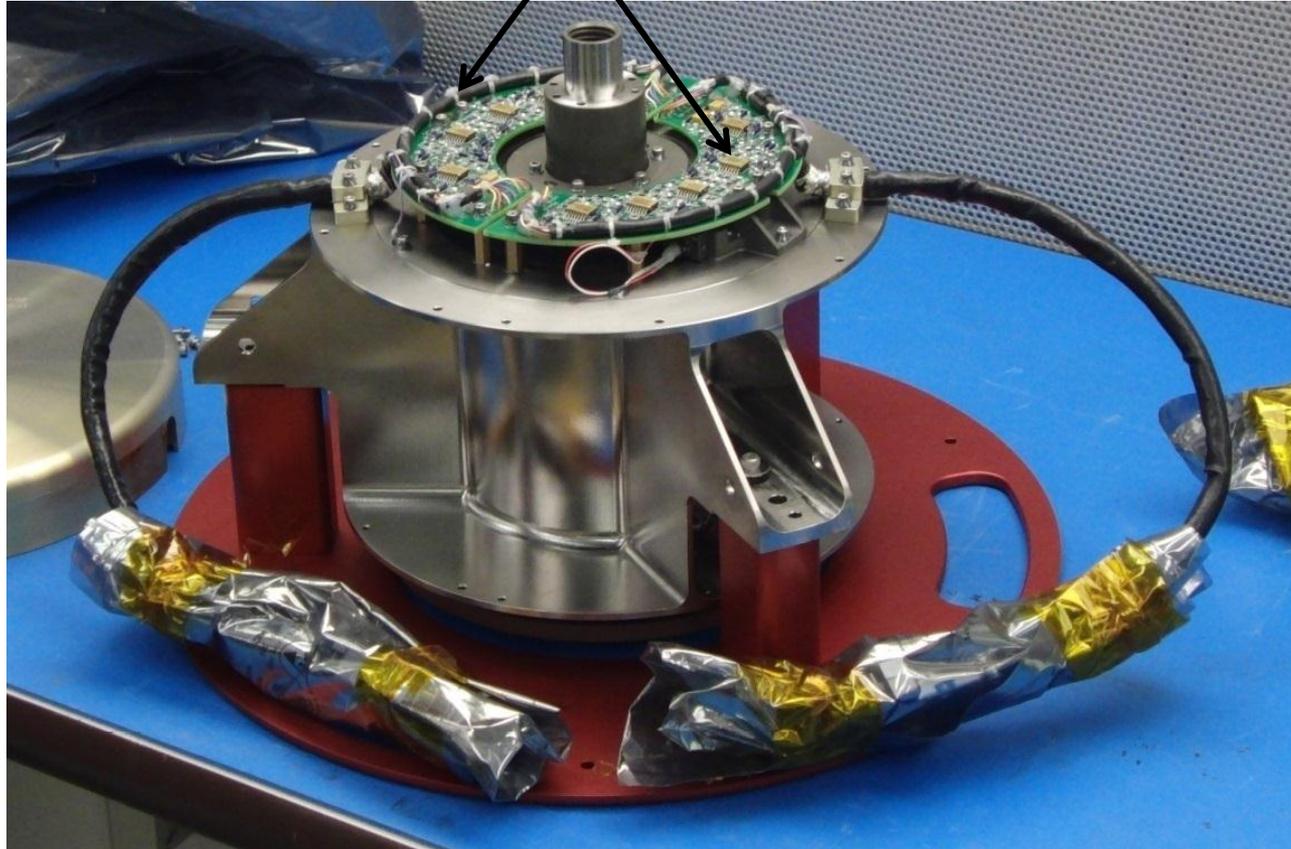
# TIR SSM and Encoder Context



# TIRS SSM Encoder Electronics

---

Redundancy

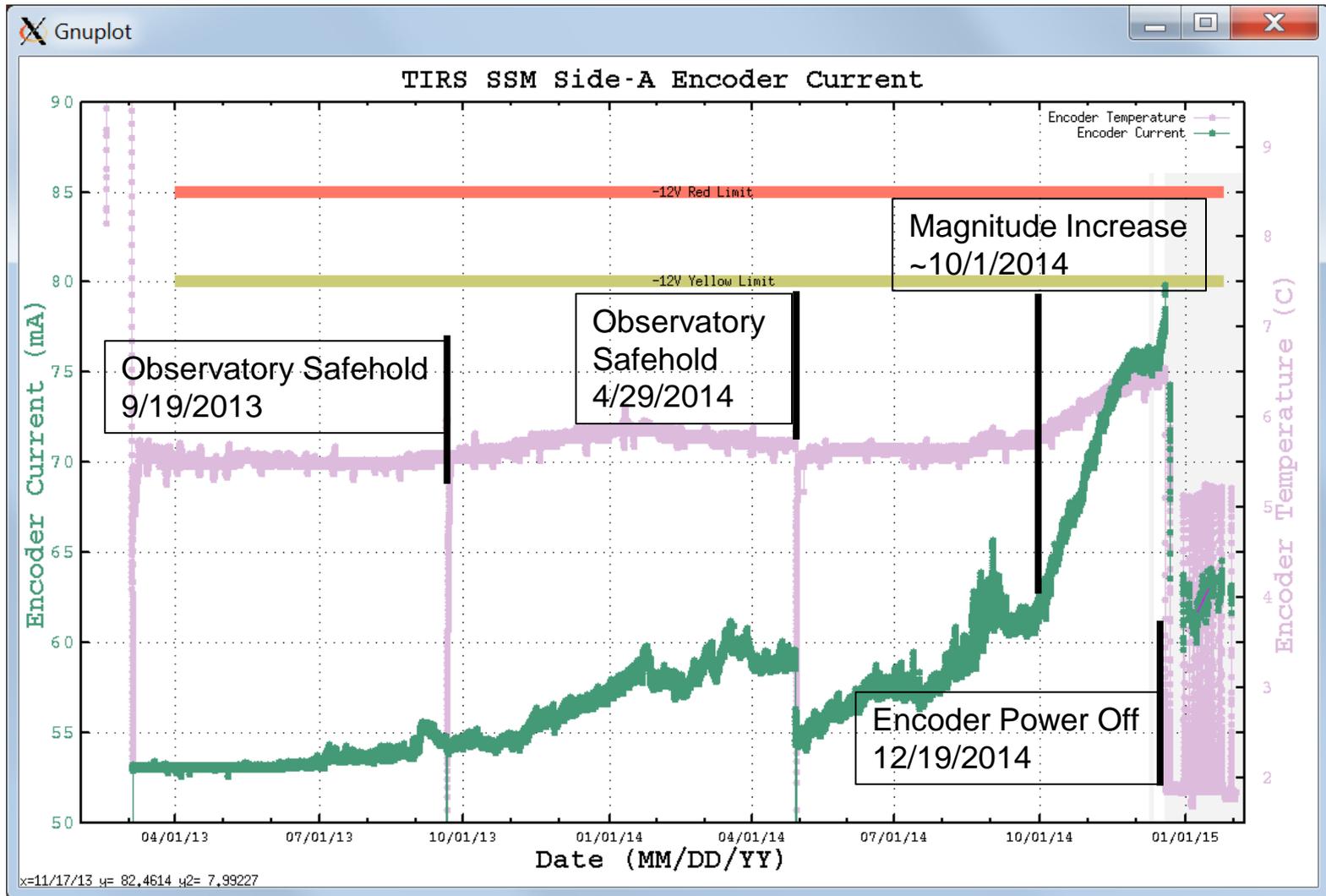


# Issue Summary

---

- In the fall of 2014 a deviation in a Mechanism Control Electronics (MCE) current was noted. Over the first year of the mission the MCE current had been stable, however starting mid-2014 the current had begun to display a noisy signature.
- Beginning in October 2014 a steady unexpected increase in current magnitude was observed. (see next slide)
- An Anomaly Resolution Board (ARB) was convened to determine the root cause and assess any hazard to the TIRS instrument.
- Based on thermal and current trends, electronics in the TIRS encoder are not behaving as expected. There has been no observed degradation in the performance of the instrument.
- Prior to launch the MCE current limits were defined based on predicted nominal circuitry degradation. The yellow limit was revised to a higher absolute threshold (from -0.075 A to -0.08 A) as the issue progressed and that threshold was reached on December 19, 2014.

# MCE Current Trend (absolute value)



# Issue Summary (cont.)

---

- It is unknown how long the current trend can continue before damaging TIRS A side electronics or how the circuitry will respond to full or unregulated 12v linear regulator output. It is also unknown if power cycling or thermally shocking components will improve or degrade the situation.
- When the encoder is disabled no encoder position is available for the CVT. The scene select mechanism position drifts when in open loop control and/or the encoder is disabled. This causes issues with data processing and correction. In roughly 72 hours the position drifts enough so the TIRS imagery begins to lose overlap with OLI imagery. When in open loop control and/or the encoder is disabled, TIRS cannot execute its normal deep space and black body calibrations.
- The TIRS instrument electronics are block redundant. If it is desirable to switch to the B side encoder read head, all instrument electronics must be swapped to the B side. TIRS B side electronics was tested during I&T without issue, however the exact on orbit state and performance of the B side electronics is unknown.

# TIRS MCE Current Anomaly Investigation

## (Cont.)

---

- 10/01: Ops and TIRS notes the –EV MCE current began to rise in magnitude
- 11/18: Possible causes collected, begin work to identify as a physical cause
- 11/25: The –EV yellow low limit was revised from -0.075 A to -0.08 A upon recommendation from the TIRS team
- 12/02: Could not correlate change in current profile to an observatory or environment event. Temp overlay plot of 2013/2014 data shows elevated read head temp confirming a physical problem. Begin outlining contingency procedures
- 12/05: Standing contingency adopted to turn off encoder if -0.08 A –EV current threshold is crossed to preserve electronics. A SSM drift test is drafted to understand how the SSM position will change over time in an open loop mode
- 12/9-12/12: Open loop SSM control commanded. A sharp tipoff was noted followed by a decaying drift rate. An off-nadir slew and propulsive maneuver did not alter the drift profile. No SSM position changes are commanded in mode zero
- 12/09: Fishbone investigation identified avenues to investigate regarding contamination, corrosion, or parts issues
- 12/12: Discussed SSM drift test results and fishbone updates
- 12/19: The –EV MCE current tripped the -0.08 A limit. The encoder was powered off as per the standing contingency
- 12/19: Reviewed side swap procedures and outlined an encoder power cycle test
- 12/22: Encoder powered on for 2 orbits (~190 min) to see if the –EV MCE current ‘healed’. Power on: -0.63 A, Power off: -0.074 A
- 12/22: The decision was made to leave TIRS on A side with the encoder off for the time being. This mode is not desirable for science. Data is being collected, however it will not be distributed to the community until corrected (at least 1 mo.)
- 12/30: SSM drift profile looks consistent w/ the 12/19 drift test. Fishbone was discussed – possible causes identified, none appear likely. More data needed. Will cycle encoder every 3 days for one orbit to observe power up characteristics. Data to be used in circuit modeling
- 12/31: Encoder powered on for one orbit (~95 min)

# USGS Objective

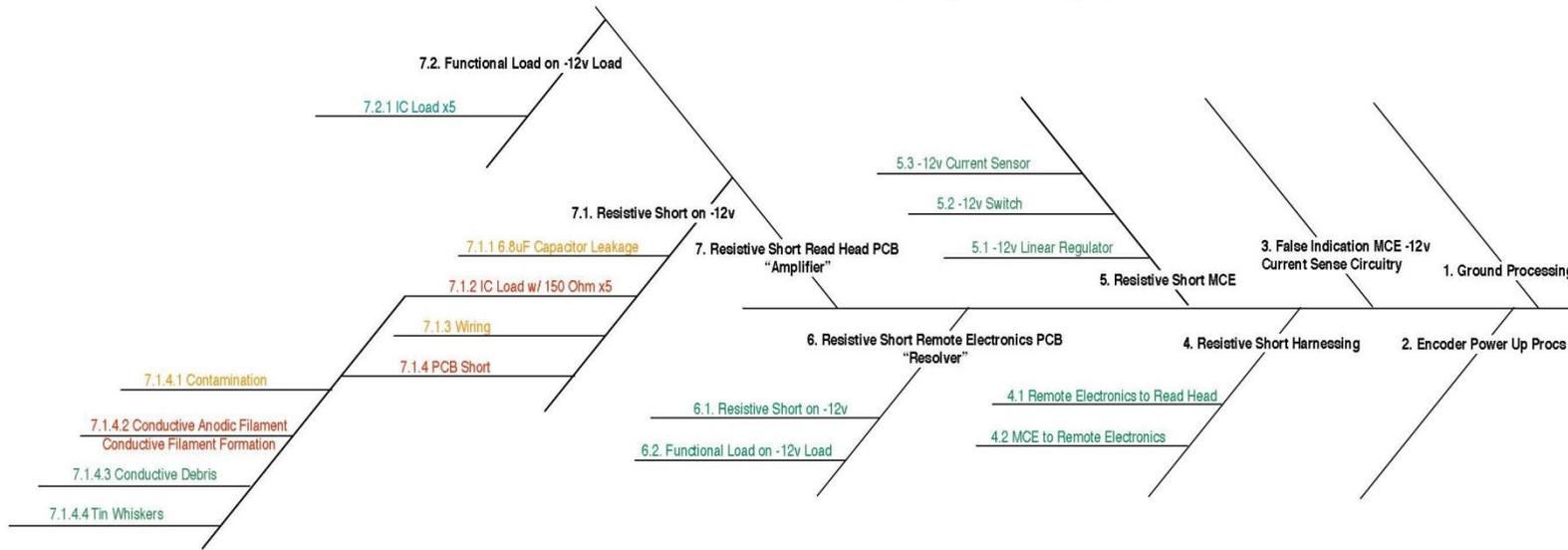
---

**To resume the operation of the TIRS instrument and daily distribution of its data as soon as possible with an emphasis on supporting the 2015 northern hemisphere growing season. Options on how to return to operations will be evaluated to determine how best to assure the collection and distribution of TIRS data by maintaining data continuity within programmatic constraints without compromising TIRS instrument life.**

# Root Cause Investigation: Anomaly Fishbone

## TIRS Increasing -12v Current Fishbone

Green: Unlikely Proximate Cause:  
 Yellow: Possible Contributing Cause:  
 Red: Possible Cause:



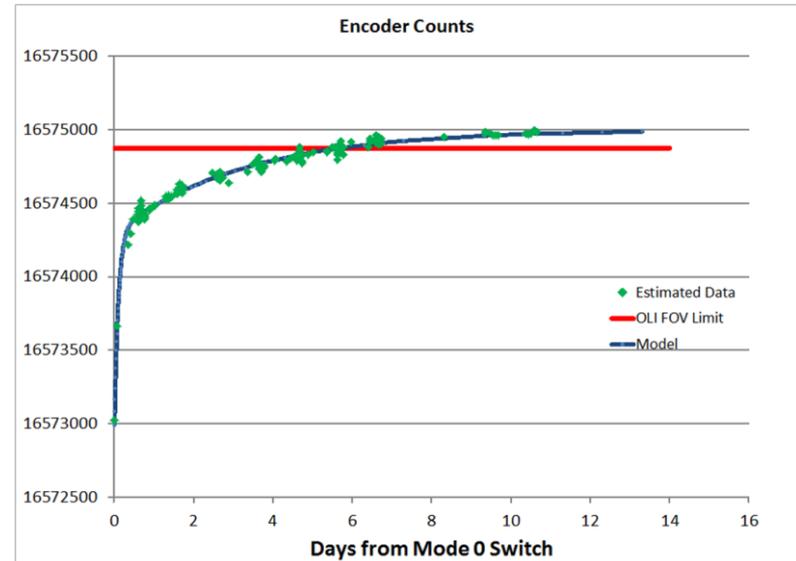
**-12v Current Increasing**

- Generally increasing current but erratic over months then accelerating over a period of days up to 25ma or equivalent to a 480 ohm load, 0.3W
- 15v current also changes and follows -12v
- Temperature increases locally to Read Head PCB, Remote Electronics PCB and rest of system shows no change
- Current decreases / recovers "heals" when off for days or hours
- Heals to lower a 62ma level, however remains about 10ma above normal 52 ma, or 1200 ohms equivalent
- Daily duty cycle of 1.5 hours on followed by off period appears steady state over a 10 day timeframe
- No functional failures or noticeable performance impairment



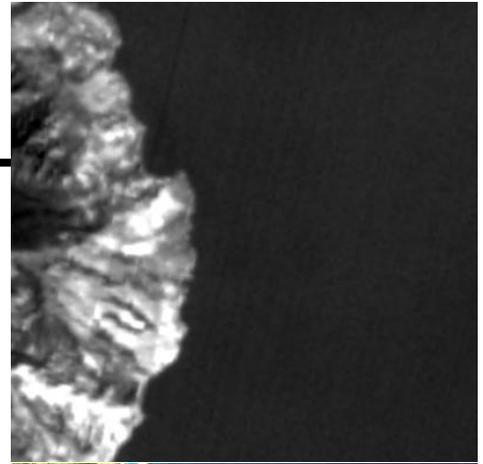
# Summary of TIRS SSM Open Loop Mode-0 vs. Closed Loop Mode-4

- TIRS SSM moved significantly when switched to mode 0
- TIRS image frame drifted slightly outside OLI image frame
  - One TIRS IFOV (pixel)
  - Drifting about one TIRS IFOV per month
- Radiometry only minimally affected (~0.2K worst case)
  - ◆ Lost capability to monitor radiometric stability
- Best science data acquired in mode 4
  - ◆ Geometrically more accurate (~15m)
  - ◆ Radiometrically more accurate (~0.2K@300K)
  - ◆ Radiometrically monitored with calibration collects



# Sample Image Shift

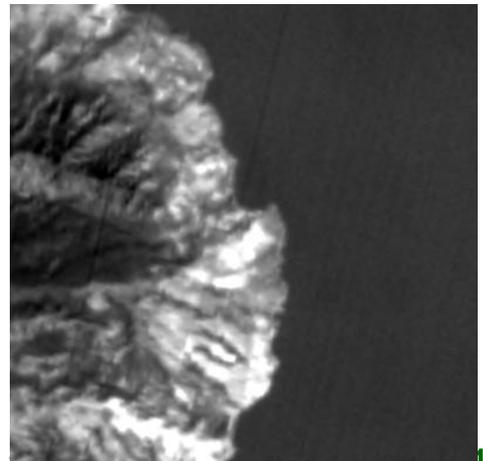
Original CPF



OLI Bands



Updated CPF



# Options being Investigated

---

1. Resume on A-side with an alternative conops
2. Resume on B-side with standard conops, and
3. A Hybrid solution where we resume standard operations on the B-side with the understanding that if the anomaly signature is detected on the B-side, we fail back over to the A-side to fully implement an alternative conops.

# Current Plan Forward

---

- **Complete on-orbit testing to determine root cause**
  - **Essentially complete**
- **Determine alternate con ops approach within the next week**
  - **Prepare for mode 0 (open loop) operations on side A**
- **Prepare and present options and recommendation to PDB late next week**
- **Brief Landsat Science Team at meeting 2/3/2015**
- **ARB this afternoon**
  - **May have new information that may influence the path forward**

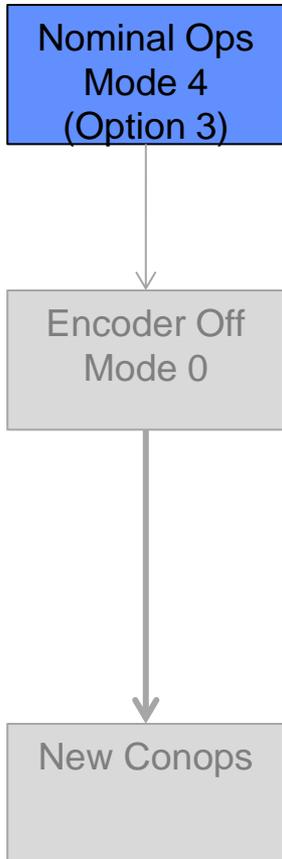
---

# Backup Slides



# Available Options

## TIRS Side B

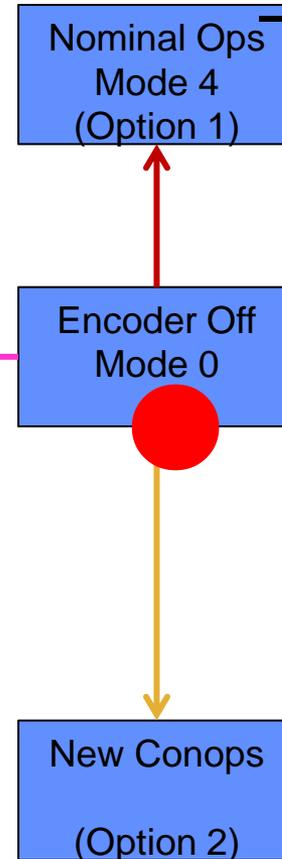


**Risk 3a:** The B side may have an unrelated issue  
**Mitigation:** Have tested procedure to return to side A. Executed numerous times in I&T.

**Risk 3b:** The issue impacting the A side may start on the B side  
**Mitigation:** The anomaly has a slow progression. Identify early and work (or revisit work on) alternate conops

**Risk 3c:** There may be an issue with the side swap process  
**Mitigation:** Swapping sides was executed multiple times in I&T and have tested contingencies..

## TIRS Side A



**Risk 1a:** Continued use may damage A side MCE electronics  
**Mitigation:** Failover to B side.  
**Mitigation:** Alt conops  
**Mitigation:** Understand risk w/ spice model  
**Note:** Status of B side is unconfirmed

**Risk 2a:** Use may damage A side MCE electronics  
**Mitigation:** Failover to B side.  
**Note:** Status of B side is unconfirmed

**Risk 2b:** Effectiveness and longterm stability unknown  
**Mitigation:** Would need to create a detailed test plan and prove it can meet long term performance and stability requirements.  
**Mitigation:** Understand SSM drift occurs and leverage in an alternate conops

**Risk 2c:** More complex operations and higher operations costs  
**Mitigation:** Reduce performance goals  
**Mitigation:** Adapt opscon

● You are here



# Candidate Conops

---

- Testing is continuing to narrow down the cause of the TIRS anomalous behavior and also to better understand the performance of the encoder if operated using alternate operating procedures
- The following three concepts have been identified as spanning the range of leading candidates
  1. Continued operation on the A-side electronics using an alternate conops to prolong its operability
  2. Transition to operating on the pristine B-side electronics and resume with standard operating procedures (following an initial 1-month initialization period)
  3. Follow a hybrid approach where the FOT initially transitions to the B-side and transition back to an A-side alternate conops only if the anomaly develops on the B-side

# 1. Resume on A-Side w/ Alternate Conops

---

## ▪ Prerequisites

- Complete all necessary A-side anomaly investigation and alternate conops functional testing
- Testing must show that data collected can meet science and operational objectives
- Space segment operations and maintenance must be acceptable
- Ground processing Cal/Val and product generation must be acceptable and cost effective
- Flight and ground segment tools, procedures and software must be updated to accommodate new conops and calval requirements

## ▪ Pros

- Meets data requirements while operating on the A-side, leaving B-side pristine
- Will likely extend TIRS operational life wrt this anomaly
- Allows team to evaluate the long-term effects and performance of the alternate conops, informing B-side decisions should TIRS one day transition to B-side (for whatever reason)

## ▪ Cons

- Will impact radiometric quality and likely geometric quality, but not to an unacceptable extent
- Ground operations costs will increase by approximately \$\*\*\*/year
- Amount of testing and development time to ensure conops can meet science/operations objectives and to characterize long term costs and impacts is unknown
- Will have unnecessarily incurred (currently unknown level of) loss of data quality and higher operational costs if B side electronics are nominal.

## 2. Resume on B-Side w/ Std. Conops

---

- **Prerequisites:**

- Complete all necessary A-side anomaly investigation and alternate conops functional testing prior to transition to B-side
- Fully functional B-side electronics (including all redundant electronics)
- Complete  $\approx$ 1-month B-Side initialization process and update ground processing calibration coefficients

- **Pros:**

- A successful transition results in resumption of fully nominal flight and ground operations
- TIRS data will be of equivalent quality as pre-anomaly A-side imagery
- If B-side does not suffer same anomaly, least impact to TIRS mission

- **Cons:**

- Requires full-instrument transition to the B-side electronics, not just the encoder electronics
- If A-side anomaly appears on B-side, team must implement an alternate conops without knowing long-term impact to anomalous electronics, potentially shortening the TIRS operational life

# 3. Hybrid Solution: B-Side->A-Side

---

- **Prerequisites:**
  - **All Candidate 1 and 2 prerequisites:**
    - Complete all necessary A-side anomaly investigation and alternate conops functional testing prior to transition to B-side
    - Testing must show that data collected can meet science and operational objectives
    - Space segment operations and maintenance must be acceptable
    - Ground processing Cal/Val and product generation must be acceptable and cost effective
    - Flight and ground segment tools, procedures and software must be updated to accommodate new conops and calval requirements
    - Fully functional B-side electronics (including all redundant electronics)
    - Complete ≈1-month B-Side initialization process and update ground processing calibration coefficients
- **Pros:**
  - A successful transition results in resumption of fully nominal flight and ground operations
  - TIRS data will be of equivalent quality as pre-anomaly A-side imagery while B-side nominal
  - Early anomaly detection on B-side triggers fallback to A-side and alternate conops, allowing team to evaluate long-term impacts and performance
    - If alternate conops is successful, operations continue on A-side
    - If alternate conops proves unacceptable, resume B-side standard operations in nominal 'Mode 4' conops until the ultimate failure of B-side and end of TIRS data collection
  - Allows collection of data in preferred 'Mode 4' for maximum period while retaining the flexibility to maximize the operational life of the TIRS instrument
  - Defers costs of further developing the alternate opscon functionality into a fully realized opscon until it is known the alternate opscon is actually needed.
- **Cons:**
  - Requires a transition to B-side from a *functional* A-side (with compromised quality)
  - Assumes an ability to successfully perform multiple 'side-swaps' of the TIRS electronics