Chandra to Hitomi Lessons learned

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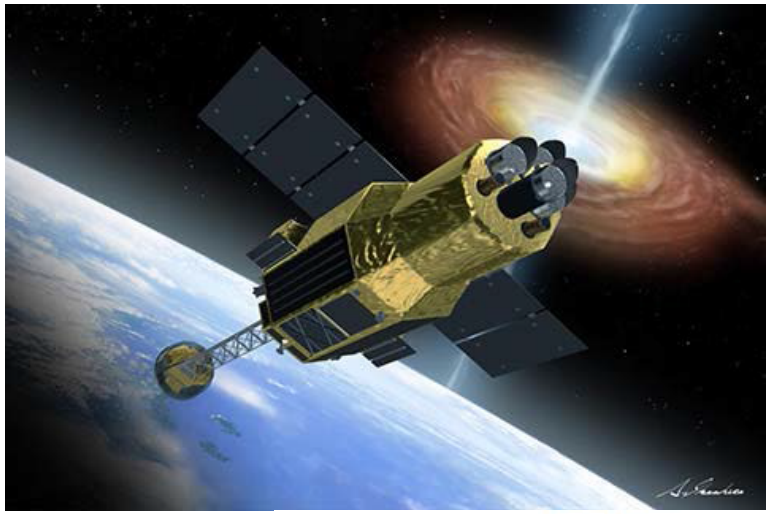
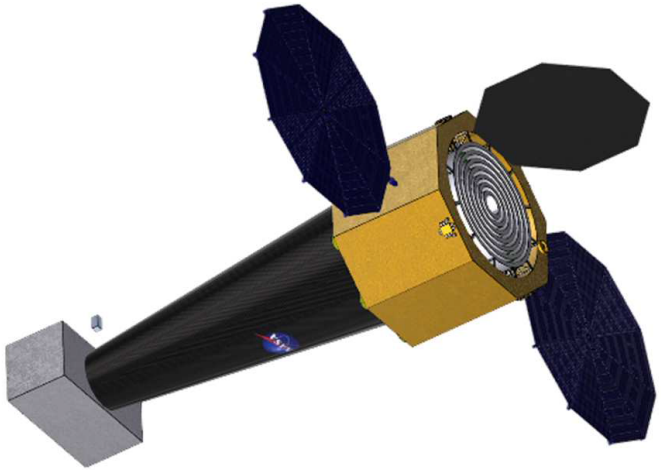
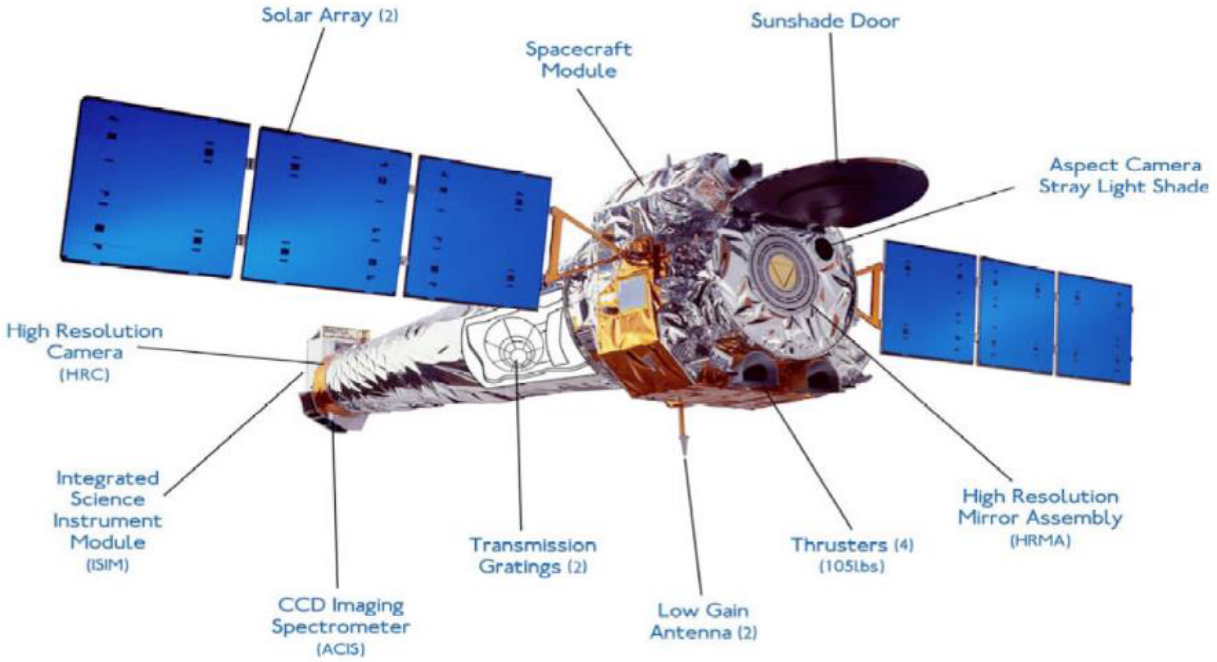
26 July 2016, STDT F2F I







1.-What would have happened on Chandra?

2. - Where were the critical problems?

3. - How could they have been prevented?

4.- What can we as a team learn from this?

1. Multiple safe mode triggers would be in play
   - large IRU bias
   - false roll indication
   - large roll rate
   - high momentum state
   - attitude mis-compare
   - solar array position error
   - power system flag

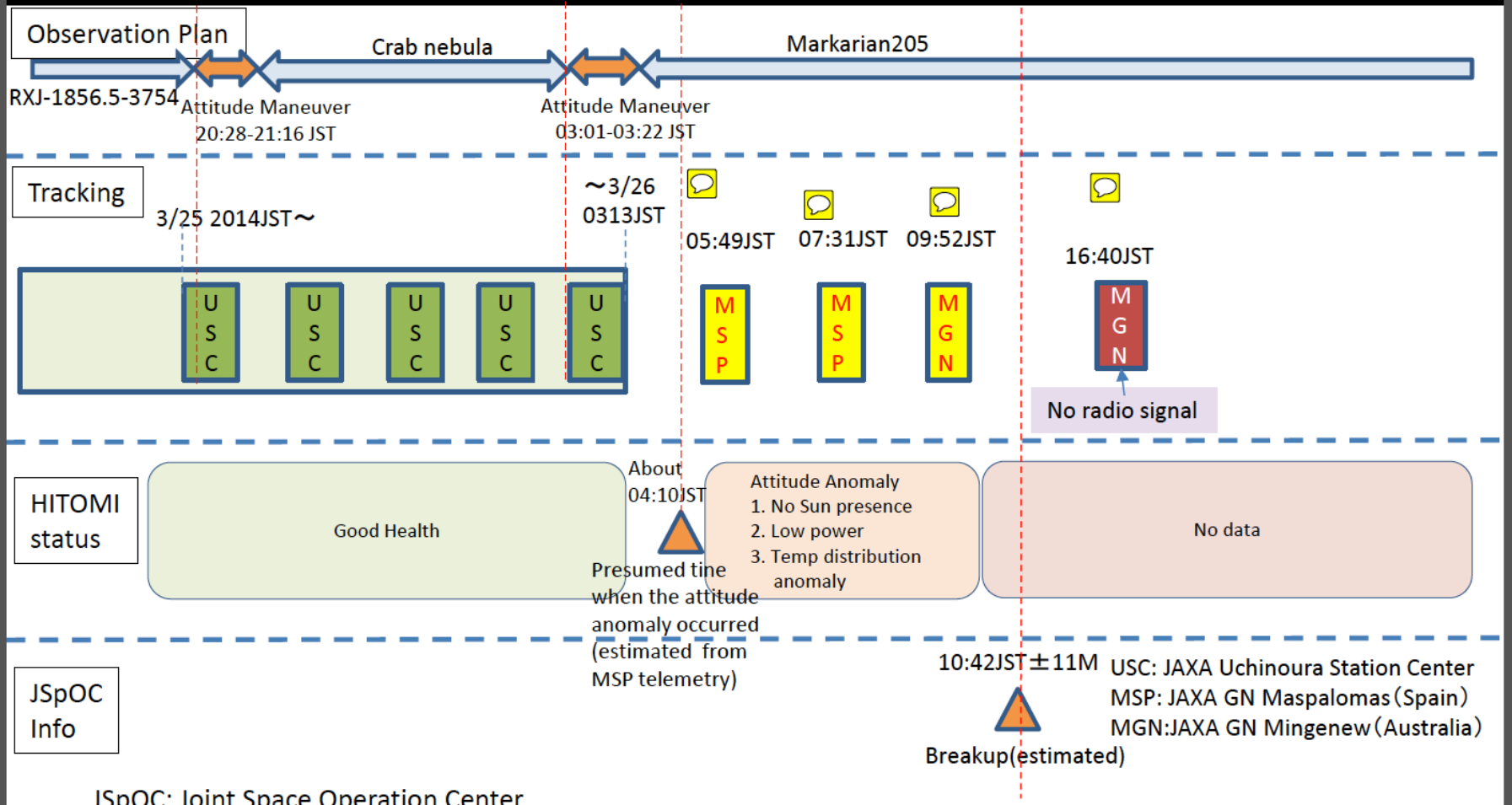
4. New Chandra planning constraint

   No gyro hold when out of sun sensor FOV (never done)

Studying several further detailed changes

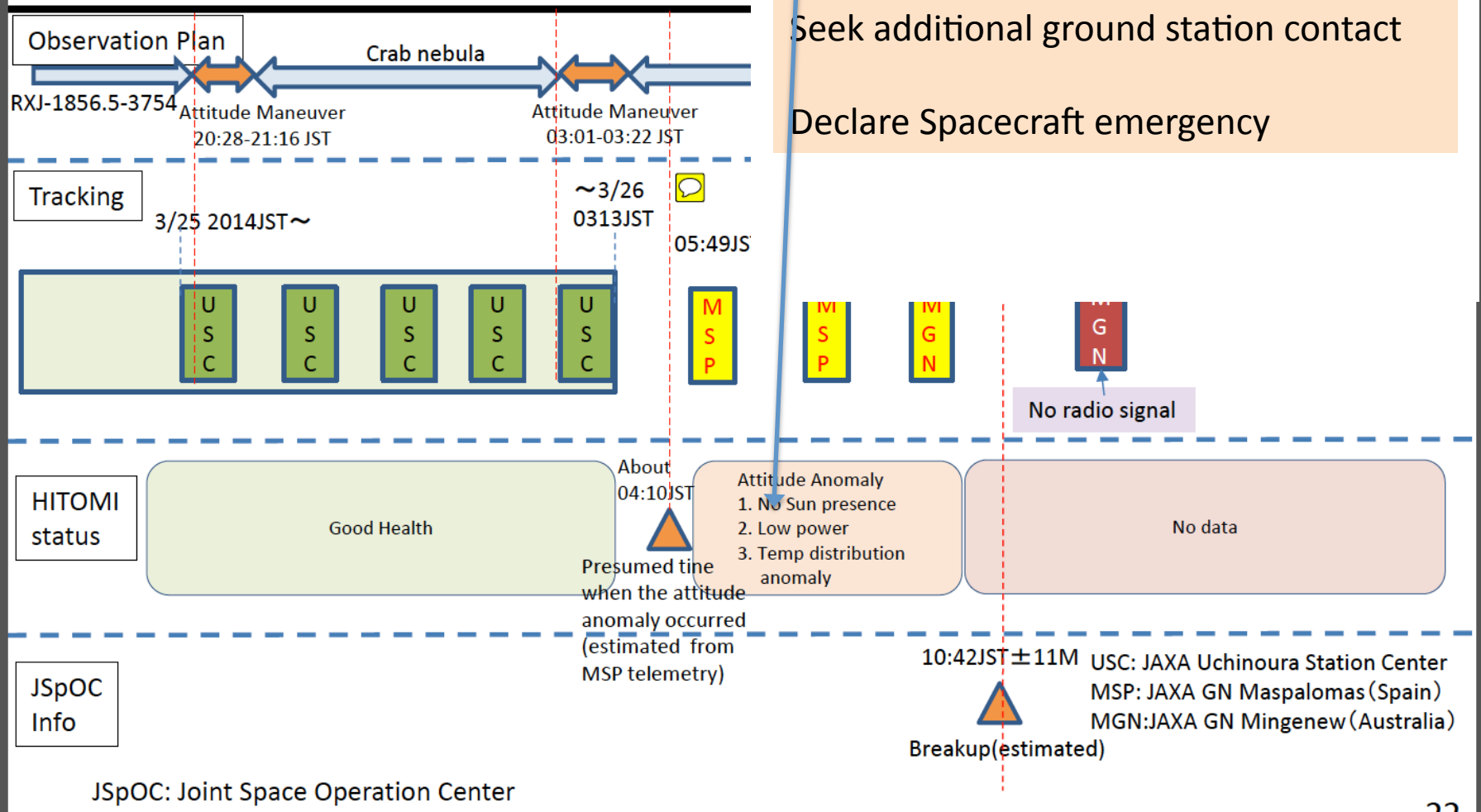
3.2 ASTRO-H Sequence of Event

The chart below shows a time sequence for the observation plan, satellite tracking, satellite condition on each events, and JSpOC information.



Expected CHANDRA RESPONSE

The chart below shows a time sequen
tracking, satellite condition on each eve



05:52 Automatic alarms trigger pagers.
05:55 Community telecon

Seek additional ground station contact

Declare Spacecraft emergency

JSpOC: Joint Space Operation Center

Mech 1. Attitude control system (ACS) caused incorrect determination as rotating,
CHANDRA: Gyro mis-compare OR Attitude monitor triggers safe mode.
(possibly Chandra goes into bright star hold earlier)
Reaction Wheel activated to stop the erroneous rotation indication, led to the rotation of satellite.
CHANDRA: Rate monitor triggers safe mode.

Mech 2. Unloading(*) of angular velocity by Magnetic Torquer operated by ACS did not work properly.
CHANDRA: Not applicable
The angular momentum kept accumulating in RW.
CHANDRA: Momentum wheels auto-unload by firing thrusters.

Mech 3. Thrusters were used. An atypical (erroneous?) command to the thrusters accelerated the satellite rotation.
Chandra: Thruster duration OR thruster duty cycle OR rate monitor trigger safe mode

Mech 4. The rotation speed of the satellite exceeded the designed speed, solar array paddles (SAPs), Extensible Optical Bench (EOB) and other parts broke off.
CHANDRA: Requires simultaneous gyro, reaction wheel, thruster failures.

IF in safe mode for other reasons, Chandra COULD be vulnerable to gyro and/or multiple PCAD failures.

Chandra operations concepts

- Chandra functioned as a single team, MSFC/TRW and contractors/ SAO/CXC/IPI
- Operations support provided by Prime Contractor, TRW.
  - All operations co-located in Cambridge.
  - personnel certified at their operational position
  - E-T-E rehearsals including anomalies
- Chandra did not split bus/mission, science/engineering.
  - FOT fully responsible under contract to SAO, in turn to MSFC
- Chandra: each functional element (e.g., subsystem), verifies stored command loads
- Real time data from all DSN stations available at OCC
  - Automated limit checking of telemetry
  - SOT automated limit checking, added computed quantities
- System design required to survive 72 hours autonomously

Chandra on-board software update process

Patch request review

Design review

Code review

Test on ASVT

Test report review

Command Action Procedure review

- Installation CAP
- Backup CAP

Memory dump and compare

Lessons learned references

Schwartz, D.~A., 2014, Proc. SPIE , 9144, 91440S

Weisskopf, M.~C., Tananbaum, H., Tucker, W., et al., 2014, Proc. SPIE , 9144, 91440P

Arenberg, J., Matthews, G., Atkinson, C., et al., 2014, Proc. SPIE , 9144, 91440Q

And the NASA lessons learned database at
http://llis.nasa.gov/