Chandra to Hitomi Lessons learned

Dan Schwartz
SAO/CXC
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.

Observation Plan
RXJ-1856.5-3754
Attitude Maneuver
20:28-21:16 JST

Crab nebula

Attitude Maneuver
03:01-03:22 JST

Markarian205

Tracking
3/25 2014JST ~

USC
USC
USC
USC
USC
USC

MSP
MSP
MSP
MGN

No radio signal

HITOMI status
Good Health
Presumed time
when the attitude
anomaly occurred
(estimted from
MSP telemetry)

Attitude Anomaly
1. No Sun presence
2. Low power
3. Temp distribution
anomaly

About
04:10JST

JSpOC Info

JSpOC: Joint Space Operation Center

10:42JST ± 11M
USC: JAXA Uchinoura Station Center
MSP: JAXA GN Maspalomas (Spain)
MGN: JAXA GN Mingenew (Australia)

Breakup (estimated)
**Expected CHANDRA RESPONSE**

The chart below shows a time sequence of events to be tracked, satellite condition on each event.

- **05:52** Automatic alarms trigger pagers.
- **05:55** Community telecon
  - Seek additional ground station contact
  - Declare Spacecraft emergency

---

**Tracking**

- RXJ-1856.5-3754
  - Observation Plan
  - Crab nebula
- Attitude Maneuver
  - 20:28-21:16 JST
  - 03:01-03:22 JST
- 3/25 2014 JST ~ 3/26 0313JST
- 05:49 JST
- No radio signal
- No data

**JSpOC: Joint Space Operation Center**

- **JSpOC**

---

**HITOMI status**

- Good Health
- Attitude Anomaly
  - 1. No Sun presence
  - 2. Low power
  - 3. Temp distribution anomaly

- Presumed time when the attitude anomaly occurred (estimated from MSP telemetry)
- US: JAXA Uchinoura Station Center
  - MSP: JAXA GN Maspalomas (Spain)
  - MGN: JAXA GN Mingenew (Australia)
- Breakup (estimated)
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


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