NuSTAR Lessons Learned

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**NuSTAR Project Overview**

**Summary**
- Small Explorer (105 M$ A/B/CD$ cap)
- High Energy X-ray focusing telescope
- Phase B start: 2/25/08, Launch: 6/13/12
- 2-year prime mission
- GO phase began 2015, now in AO3
- Category 3, Class D (enhanced) mission

**Major Partners**
- Caltech (PI, instrument)
- JPL (management, systems engineering)
- UCB (instrument, mission operations)
- Orbital (S/C)
- ATK (extendible mast, instrument structures)
- GSFC (optics, archive)
- Columbia (optics)
- DTU (optics)
- ASI (ground station, analysis pipeline)

**Mission Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Launch Mass</td>
<td>350 kg</td>
</tr>
<tr>
<td>Payload mass</td>
<td>173 kg</td>
</tr>
<tr>
<td>Power</td>
<td>600 W</td>
</tr>
<tr>
<td>Launch Vehicle</td>
<td>Pegasus XL, Kwajalein launch</td>
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<tr>
<td>Orbit</td>
<td>650 x 610 km, 6° LEO</td>
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Payload and Science

<table>
<thead>
<tr>
<th>Instrument Parameters</th>
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<tbody>
<tr>
<td>Telescope</td>
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<tr>
<td>Focal length</td>
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<tr>
<td>Spatial resolution</td>
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<tr>
<td>FoV</td>
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<tr>
<td>Source positioning</td>
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- **Survey deep extragalactic fields to study the evolution of supermassive black holes**
- **Survey Galactic fields to study populations of stellar remnant black holes and neutron stars**
- **Map the young remnants of exploded stars in radioactivity**
- **Observe core collapse supernovae in the Local Group and nearby Type 1a SNe**

343 publications to date, 5400 citations
NuSTAR Challenges

- Hardware distributed over multiple partners
- Mass margin was low from day 1
  » Required extremely careful management
- Optics - ~500 segments, distributed fabrication (GSFC, Denmark, Columbia)
  » Control of process was challenging
- Extendible mast
  » Many parts, testing challenging,
- Many mechanisms, difficult testing
- Mission classification (‘enhanced’ class D) was new – nobody really knew what it meant
Lessons Learned

• Technical and Leadership team and organization is key
  » Project success is determined by the technical quality of the project team – choose carefully
  » Stable leadership is critical – no changes in high level organization
  » Adopt a flat management approach – key people must communicate without a mid-management layer
  » If working with a center, make sure there is an agreement on stability of top level personnel
Lessons Learned

• Beware of heritage
  » Heritage claims tend to erode on closer review
  » Heritage resides in people, not organizations
    • learned this the hard way with the deployable mast
  » Seemingly small changes or scaling can be challenging
    • Detectors were custom, repackaging from balloon format and more rigorous environmental requirements led to major issues

• Takeaway: heritage arguments can lead to over-confidence, and often come back to bite
Lessons Learned

• Try to reduce process oriented work – it often adds insufficient value for the large effort
  » We adopted an EVM-lite approach and got center buy in
  » Tailoring JPL’s mission assurance plan was essential given our cost/schedule constraints
  » Tailored JPL’s oversight requirements on contracts

• Negotiate and obtain center-level agreement early on
Lessons Learned

• Strong, independent reviews can be helpful
  » Choose SRB members carefully for directly relevant experience.
    • Can rely on technical expertise
    • Make sure SRB members are SMEX-experienced
  » Develop a good working relationship with board members
  » Involve SRB members in system and subsystem reviews – leads to smoother mission-level reviews
  » Peer reviews with carefully chosen technical experts can add real value
Lessons Learned

• Decide science team roles and responsibilities early and formalize them
  » Your first senior review will be there before you know it

• Setting the structure, expectations and responsibilities long before launch is important

• NuSTAR’s approach was to structure working groups, appoint senior leaders, but set an expectation/culture that junior scientists would be leads
  » worked well to minimize conflict and get results out in a timely way