THEMIS Mission Phases

Goals:

- Describe the activities occuring in, and disposition of the THEMIS probes during each of the mission phases.
- Begin discussion of data acquisition strategies during each mission phase, and constraints upon those strategies imposed by mission resources and design.

Mission Phases:

- Launch and Early Orbit
- First Year Tail Season: Setup, In-Season Maneuvers.
- After the Tail: Flanks and Dayside.
- Second Year: Tail Conjunctions, etc.
- Third Year/Extended Mission (Phase F): Evolving Orbital Orientations, Conjunctions with MMS.
- End of Mission

Launch and Early Orbit

- Injection Orbit: 21 Aug. 2006, 1.1x12.1 Re, INCL 9, APER 0, RAAN 330, apogee on dayside.
- Probes separate from PCA, deploy MAG booms, perform instrument checkout.
- P3-5 are placed in their initial science orbits, and deploy and commission EFI sensors:

P3,4 1.1x12.1 Re, INCL 9 (minor adjustments for LV/PCA dispersions).

P5 1.1x9.8 Re, INCL 4 (18-hr period).

- P1,2 remain in the injection orbit to:
  - minimize differential precession in APER and RAAN between the inner (P3-5) and outer (P1-2) probes.
  - reduce INCL drift and fuel required to conteract it the first year, leaving margin for third year/extended mission maneuvers.
- Radiation belt, flank MP and sheath, and inner edge of the plasma sheet observations can begin immediately on P3-5 (P1-2 as well, sans EFI).

First-Year Tail Season: Setup, In-Season Maneuvers.

- P1 and P2 are placed into their initial science orbits, and deploy and commision EFI sensors. If P1 or P2 need to be replaced, then either P3 or P4 will be maneuvered into replacement.

  P1 1.5x30.9 Re, INCL 10.9 (drifts down to ≈ 7).

  P2 1.2x19.8 Re, INCL 8.9 (drifts down to ≈ 7).

- In-season adjustment of semi-major axis on probes used to change period and adjust postion in orbit (mean anomaly) to optimize probe alignments and increase number of conjunction hours.

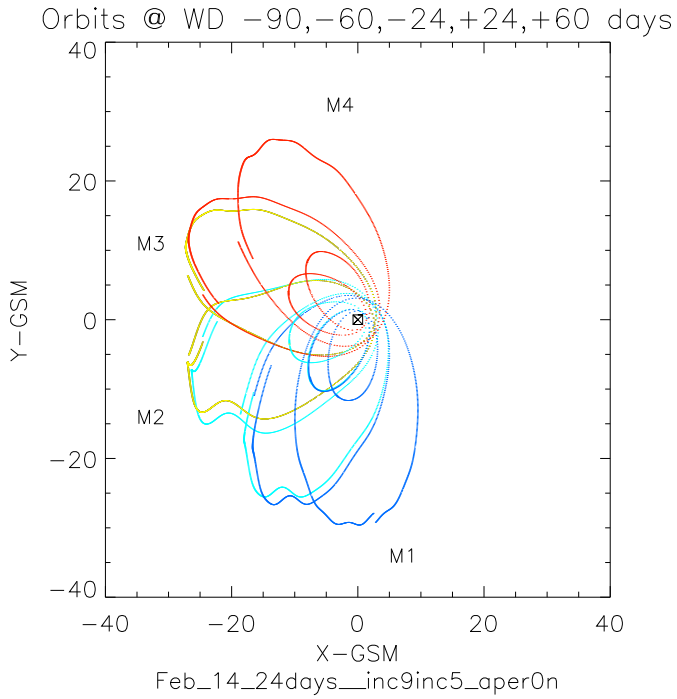
  M1 Ascent, inclination change, period tweak (Tail Wedding Day -88 days; 25 Nov. 2006).

  M1' Period tweak (TWD-60 days; 23 Dec. 2006).

  M2 Period tweak (TWD-24 days; 28 Jan. 2007).

  M3 Period tweak (TWD+24 days; 17 Mar. 2007).

  M4 End-of-season 9TWD+60 days; 22 April 2007).

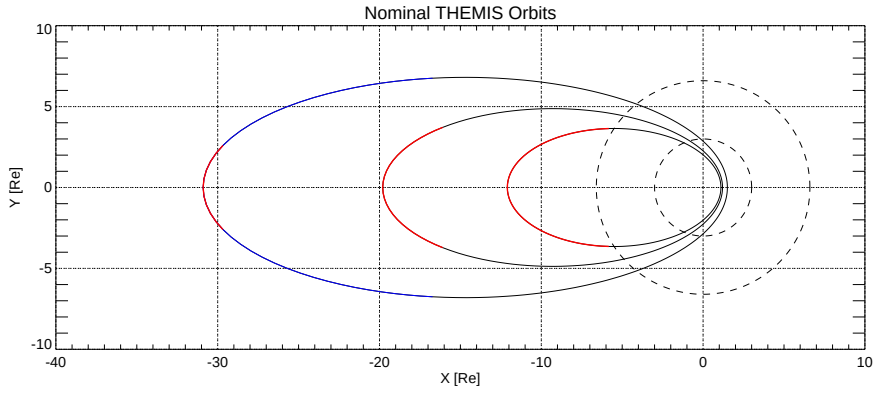


First-Year Tail Season: Conjunctions, Data-Taking Strategy

- Conjunctions:
  - The goal of the first-year tail season is to achieve at minimum 94 hours of conjunctions, with a baseline goal of >188 hours. This is predicted to allow for the capture of at least 5 (minimum) or 10 (baseline) substorms by the THEMIS constellation.
  - Studies in support of CSR (Phase-A) showed that reasonable orbital configurations that achieved over 300 hours of conjunctions per year existed, although the effects of the initial precession (absolute and differential) of the orbits in APER and RAAN were not self-consistantly accounted for.
  - Current strategy is to ensure achievement of **minimum** conjunction goals in first year, allowing P3 and P4 to use their fuel reserve for other maneuvers to enhance flank, dayside, and/or second-year tail science yield.
  - Details of current conjunction studies to be described later this morning.
- Data-Taking Strategy:
  - Current downlink resources restrict the amount of data gathered on each probe to 750 Mbits **per orbit**.

Day Number (mod 4)	P1	P2	P3-5
1	750	750	750
2	0	0	750
3	0	750	750
4	0	0	750

- Draft instrument modes presented in the CSR (Survey, PBurst, WBurst1/2) took this constraint into account, and allowed for 18-21 hours of data collection **per orbit** per probe. This limits the spatial extent of the data collection region on all probes:


Nominal THEMIS Orbits
10
5
0
-5
-10
Y [Re]
-40
-30
-20
-10
0
10
X [Re]

After The Tail: First-Year Flanks and Dayside

- P5 apogee raised to 13.2 Re – increases period to 9/8 that of P3-4, increases APER and RAAN precession rates to catch up with P3-4.
- If minimum success has been achieved, then perigees of P3-5 can be raised to somewhat reduce differential precession in APER and RAAN between the inner and outer probes.
- APER of all probes will be above 60 degrees, meaning their apogees orbits are all tipped down.
- Apogees of P3 and 4 may be raised to 13 Re to allow two-point probing of flank MP during first year, although this means access to the sub-solar MP will be sequential, rather than simultaneous.
- GSM latitude and longitude of MP/BS crossings: TBD.
- Data-taking strategy: TBD.

Second Year: Tail Conjunctions, etc.

- Conjunctions during second tail season were again predicted at > 300 hr, but were not based on self-consistant evolution of probe orbits from beginnig of mission to second tail season.
- Evolution of orbits and optimization for second year tail: TBD.

Third Year/Extended Mission (Phase F): Tail Conjunctions, MMS Conjunctions.

- Delayed ascent of P1 and P2 in first year saves fuel that could be applied towards INCL adjustments to set a third tail season. Details: TBD.
- Continued operation into third year allows for macro-scale conjunctions with first year of MMS. Details: TBD.

End of Mission

- Because the probe orbits do not lie in one of the NASA-approved graveyards, end-of-mission maneuvers are required to ensure re-entry of all probes within 10 years.
- All probes will be placed in their end-of-mission orbits at the beginning of the Extended Mission phase (May 2009). P1-2 have their periods adjusted to bring them into Lunar resonance. P3-5 have their perigees lowered to the original injection perigee to increase drag and decrease lifetime.