



FAME Science Requirements

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Primary Requirements (Level 1)



- **FAME Will Create a Catalog of Star Positions Based on a 2-1/2 Year Mission With:**
 - **A Measured Position, Parallax, and Proper Motion of Stars Between 5th to 9th Visual Magnitude to 50 Microarcseconds, 50 Microarcseconds, and 50 Microarcseconds Per Year Respectively; for Stars Fainter Than 9th Visual Magnitude the Mission Astrometric Accuracy Shall Degrade No More Rapidly Than Implied by the Photon Statistics, i.e., No More Rapidly Than the Inverse Square Root of the Apparent Brightness; at 15th Visual Magnitude the Mission Astrometric Accuracy Shall Be No Worse Than 500 Microarcseconds**
 - **Photometric Magnitudes for All Stars in the Wide Band Astrometric Bandpass As Well As the Sloan g' , r' , i' , and z' Filters**
 - **The Accuracy of Individual Observations Magnitude Will Be From Millimagnitudes at 9th Magnitude to Four Hundredths Magnitude Will Be 15th Magnitude; the Mission Magnitude Accuracies Will Be Tenths of a Millimagnitude at 9th Magnitude and Five Millimagnitudes at 15th Magnitude**
 - **The Above Accuracy Specifications Apply to 90% of the Unconfused Sources at a Given Magnitude, With the Other 10% Not Exceeding Twice the Accuracy Specification; the Coverage Is for $> 98\%$ of the Sky to Take Into Account Areas of Crowding**



Secondary Objectives



- **FAME Will Provide:**
 - Calibration of the Luminosities of the “Standard Candles” (the Galactic Cepheid Variables and the RR Lyrae Stars) That Are Fundamental in Defining the Distance Scale to Nearby Galaxies and Clusters of Galaxies
 - Calibration of the Luminosities of Solar-Neighborhood Stars, Including Population I and II Stars, Thus Enabling Diverse Studies of Stellar Evolution and Other Interesting Science; in the Case of Population II Subdwarfs, This Will Allow the Determination of the Distance and Ages of Galactic and Extragalactic Globular Clusters With Unprecedented Accuracy
 - Definitive Determination of the Frequency of Solar-Type Stars orbited by Brown Dwarf companions in the mass range of 10 to 80 M_{jup} with orbital periods up to a little longer than the duration of the mission; this will include an exploration of the transition region between giant planets and brown dwarfs, which appears to be in the range of 10 to 30 M_{jup}
 - Proper motions and distances for individual stars in star-forming regions for determination of membership, ages and kinematics
 - A study of kinematic properties of the survey to 40 million stars within 2.5 kpc of the Sun, and in particular, assess the abundance and distribution of dark matter in the Galactic disk with much greater sensitivity and completeness than previously possible



Requirements, Goals, Floor



- **Fame Will Have the Following Accuracy Requirements, Goals, and Floor for the 2-1/2 Year Mission in UAS:**

	Requirement	Goal	Floor
1. Standard Candles			
@ 9 mag	50	25	100
@12 mag	100		200
@15 mag	500	1000	
2. Solar Neighborhood Stars			
@ 9 mag	50		200
@15 mag	500	2000	
3. Brown Dwarfs			
@ 9 mag	50	25	100
@15 mag	500		
4. Star Forming Region			
@ 9 mag	50	25	100
@12 mag	100	50	200
@15 mag	500		
5. Dark Matter			
@ 9 mag	50		
@12 mag	100	400	
@15 mag	500	2000	

Note: *Requirement* is the specification to which the instrument and spacecraft are designed.
Goal is what is desired if this can be achieved within budget and schedule.
Floor is the value at which it is not worth doing the mission for this scientific purpose.



Mission Overview

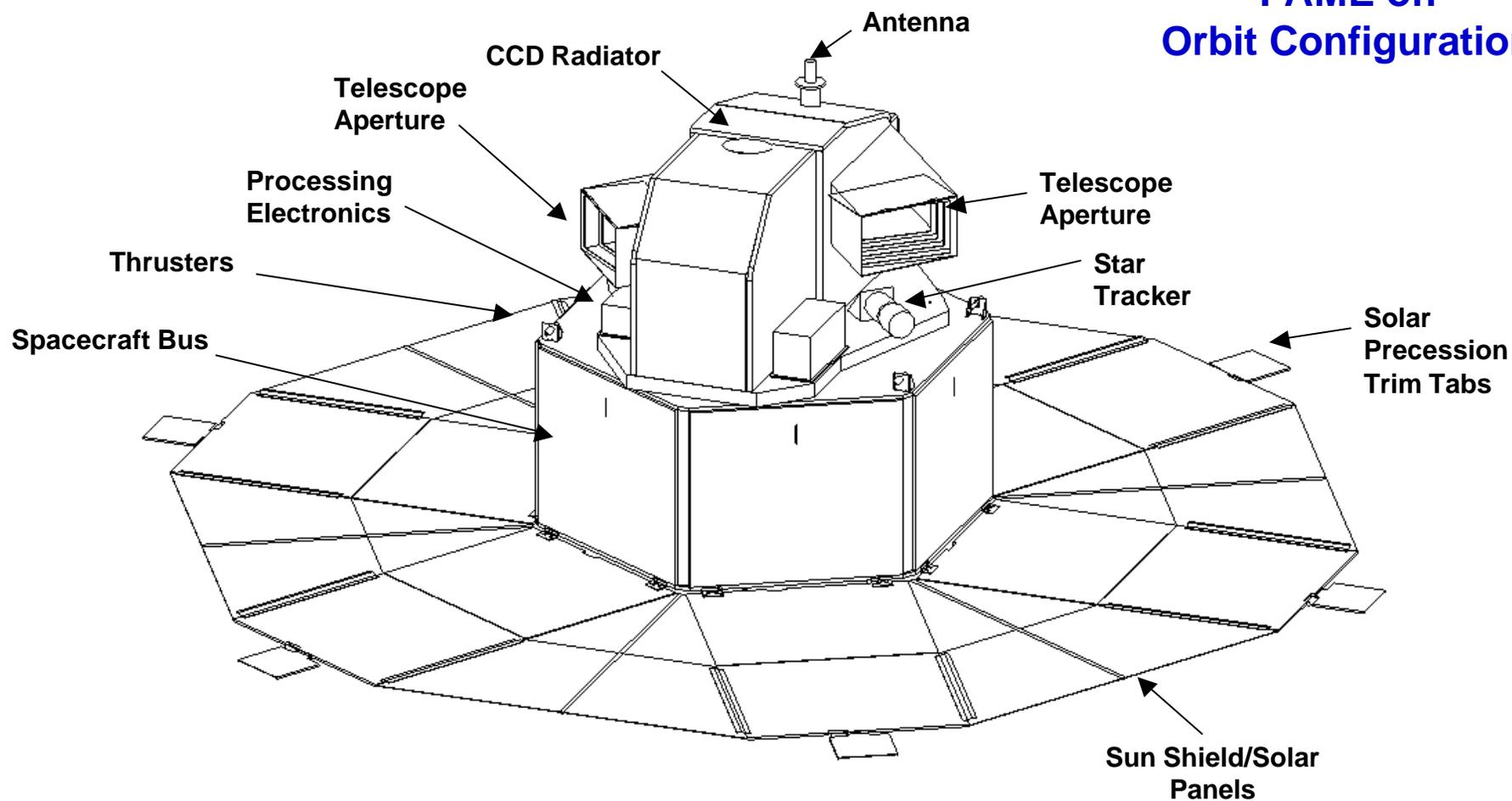
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Operational Configuration



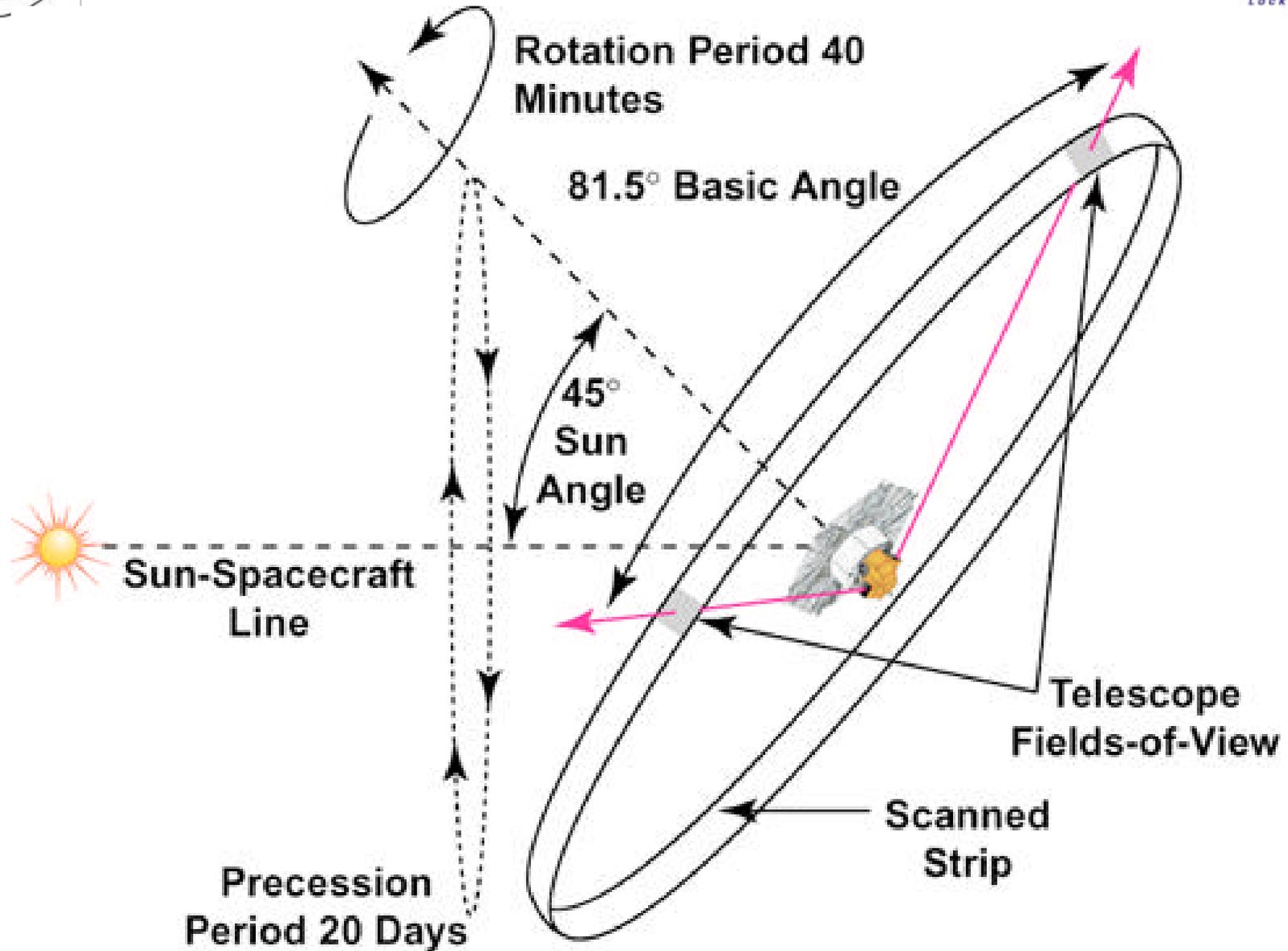
FAME on Orbit Configuration



Spacecraft Design Uses Component Heritage From *Clementine*

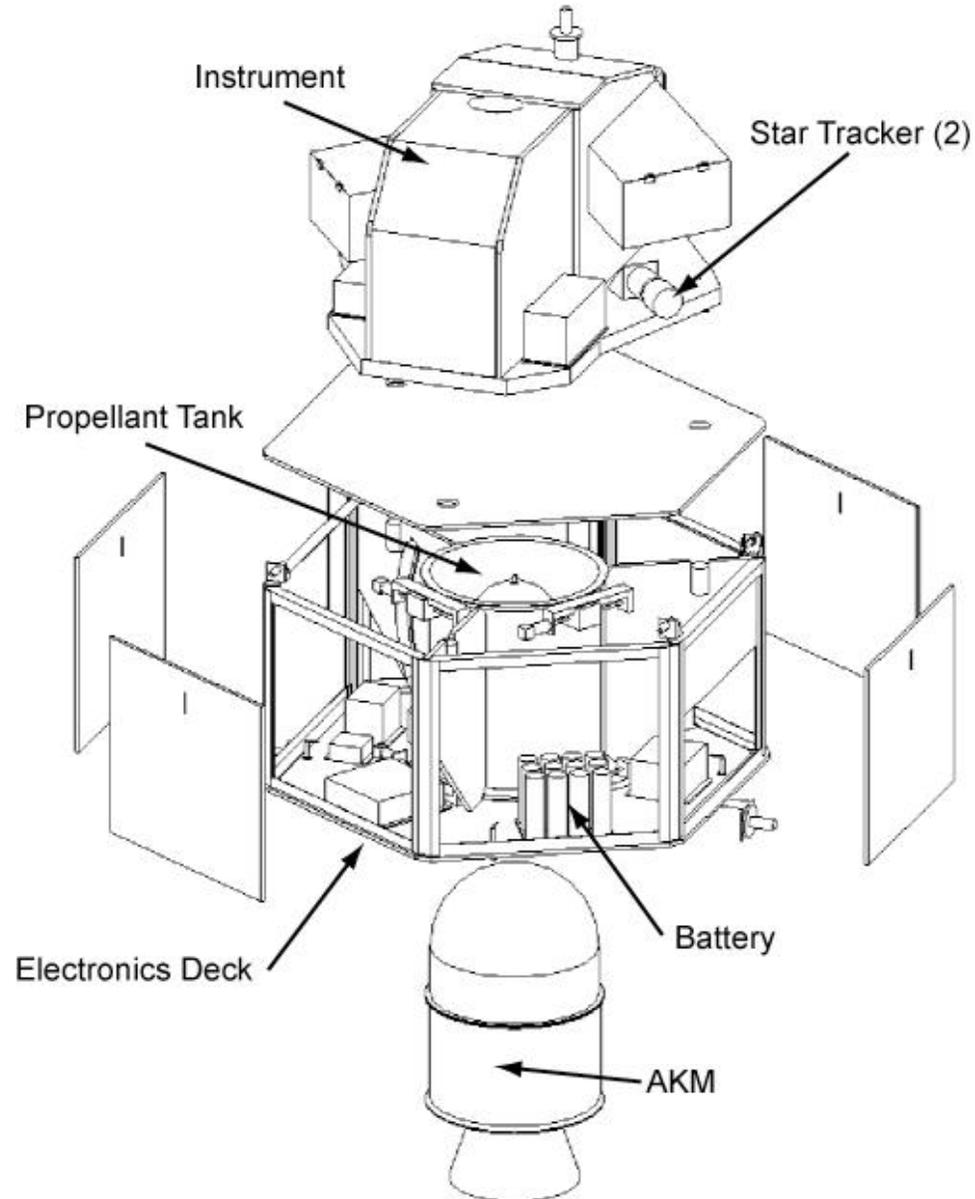


Observation Concept



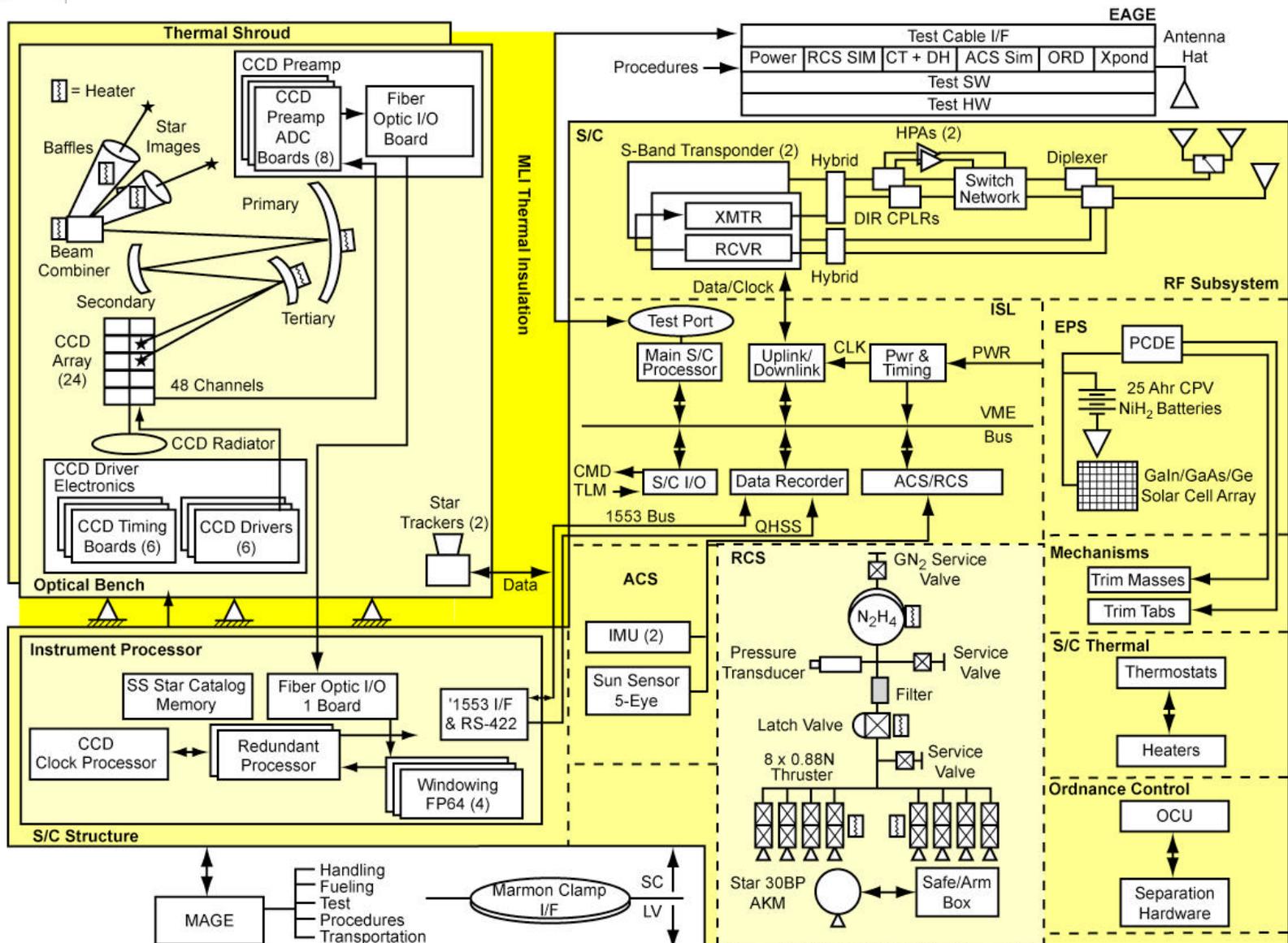


S/C Exploded View



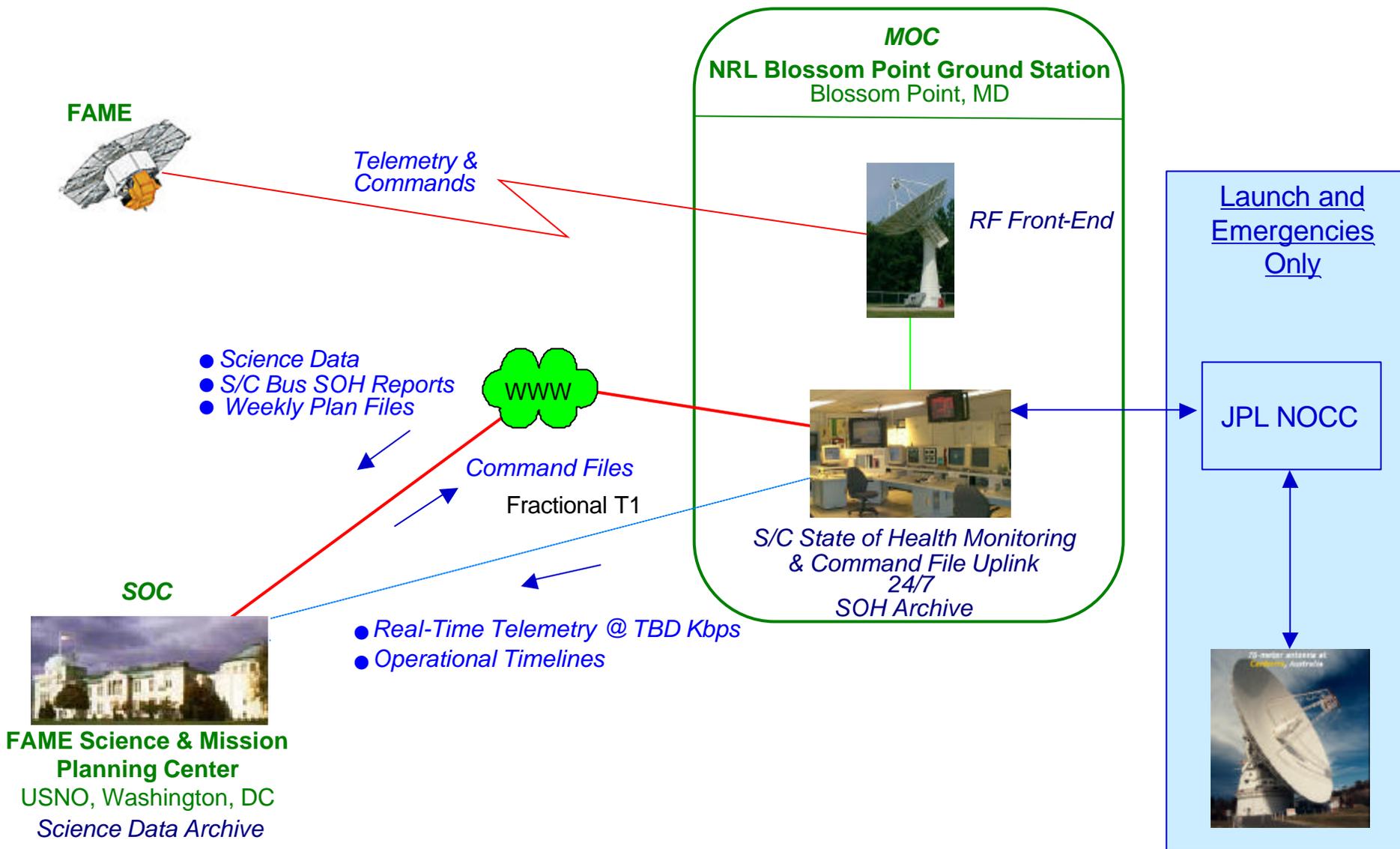


S/C Bus Block Diagram





Operations Concept





Mission Design



- **Hipparcos Style Observing Concept**
 - One Passive Observation Mode
 - No Active Attitude Compensation
- **Fixed Solar Arrays**
 - Serve As Thermal Shield for Instrument
 - Harness Solar Pressure for Spin Axis Precession
 - Collect Energy for Batteries Used During Eclipses
- **Redundancy in Selected Subsystems**
 - Balance Cost Constraints While Maximizing Reliability/Mission Success
- **Spacecraft Operates at GEO**
 - Minimize Gravitational and Magnetic Torques
 - Provides Continuous Data Downlink
- **Launch Vehicle Places Spacecraft in GTO**
 - On-Board Solid Rocket Motor (SRM) Used to Circularize Orbit
 - SRM Jettisoned to Maintain Operational Spin Balance Requirements
- **Blossom Point Used As Mission Operations Facility**
 - Augmented With DSN Support During GTO Phase



Mission Phases (1 of 3)



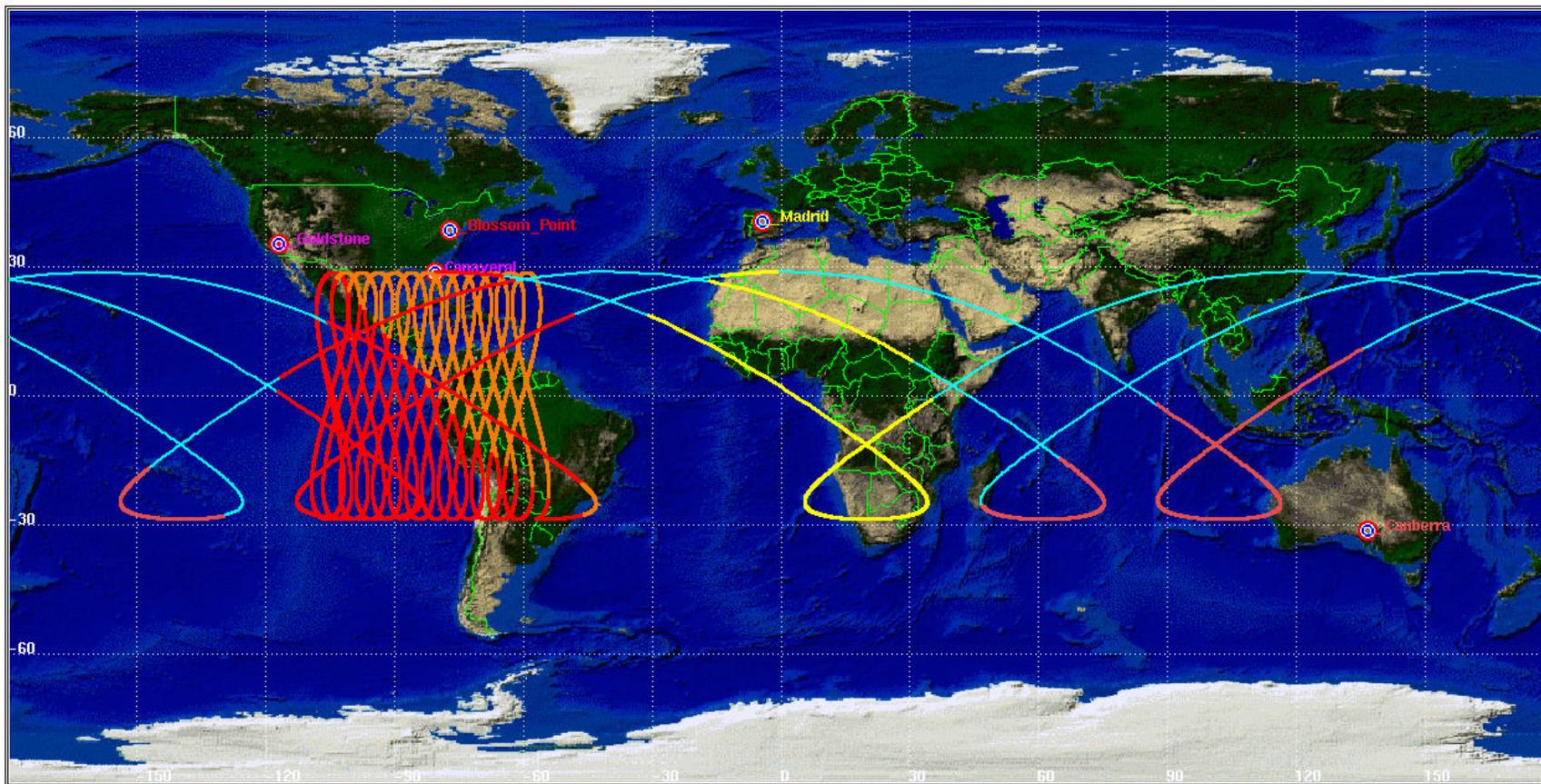
- **Nominal Launch Window**
 - Initial Launch Capability (ILC) Is June 30, 2004
 - Launch Time Constraints Driven by:
 - Desire to Minimize Eclipses During Mission Life
 - Launch Window Will Be Determined by Allowable Increase in Eclipse Duration (A 10% Increase in Eclipse Duration Allows for a Seven Hour Launch Window)
 - Initial Analysis Indicates Night Launch
- **Launch Phase**
 - Begins With First Motion of Delta 7425, Ends With Separation From the Star-48 Upper Stage
 - S/C Controller, Receivers, Sun Sensors, and Power Control Electronics Powered for Launch
 - S/C Controller Is Pre-loaded With Event/Task List Activated Upon Separation From the Third Stage
 - Solar Arrays Stowed
 - Ordnance Subsystem Is “Safed” and Cannot Be Armed Until Separation From the Third Stage



FAME Coverage During Orbit Transfer



Blossom Point + DSN Stations (2° min elev)



Joint Blossom Point/Madrid Coverage
Blossom Point Coverage
Canberra Coverage
Madrid Coverage

7/13/2000 WJB



Mission Phases (2 of 3)



- **GTO Phase (L + 27 Minutes to L + 2 1/2 Days)**
 - Begins With Separation From the Third Stage
 - 10.6 Hour Orbit; Apogee at GEO Plus 300 km (Nominal)
 - S/C Aligns -Y Axis (TBR) With Sun Line; Arrays Remain Stowed
 - Ends With Firing of Apogee Kick Motor (AKM) on Rev 5
 - Blossom Point and DSN Sites Madrid & Canberra Used During This Phase
- **SuperSync Phase (L + 2 1/2 Days to L + 13 days)**
 - Circular at GEO Plus 300 km
 - Allow Drift at SuperSync Until S/C Drifts to 105 Deg West (13 Days)
 - AKM Jettisoned in SuperSync Orbit
 - Solar Arrays Deployed, Begin Checkout of S/C Attitude Modes, S/C Bus Health Checks
 - Single Delta-V Burn to Lower Perigee to GEO Minus 300 km Ends SuperSync Phase
 - Blossom Point Is Only Required Ground Station for Remainder of Mission



Mission Phases (3 of 3)



- **Early GEO Operations (L + 13 Days to L + 30 Days)**
 - Allow Time for S/C to Out-Gas Prior to Opening Instrument Covers [Launch + 30 days (TBR)]
 - Initial Adjustments of Trim Masses/Trim Tabs Using S/C Bus Attitude Sensors
 - P/L Electrical Checks Performed (Doors Closed)
 - Orbit Determination Checkout Begins
- **EE&C Phase (L + 31 Days to L + 40 [TBR] Days)**
 - Open Instrument Covers
 - Instrument Optical Checkout/Calibration Begins
 - Additional Adjustments to Trim Masses/Trim Tabs Using Instrument Attitude Information
- **Science Phase (L + 41 Days to L + 5 Years)**
 - Science Operations
 - Baseline NASA Mission Through L + 2 1/2 Years
 - Extended Mission (Navy Funded) from L + 2 1/2 Years to L + 5 Years
- **Disposal**
 - At End of Mission; Single Burn to Raise Perigee to GEO Plus 300 km



FAME Orbit



- **Drifting Geosynchronous Elliptical Orbit**
 - **Inclination Set by Launch Site at 28.7°**
 - **Orbital Period Matches Earth Rotation**
 - **Geopotential Resonance (With J22) Causes Oscillation About Stable Longitude at 105° West (Period ~ 2.5 Years)**
 - **Choose 105° West Longitude to Minimize Longitudinal Variation**
 - **Eccentricity Set at 0.0071 to Avoid Geostationary Belt**
 - **Inclination W.R.T Ecliptic >45° to Minimize Eclipses**
 - **Constrains Launch Window**
 - **No N-S Thrusting Planned**
 - **Provided Good Initial Orbit Insertion, No E-W Station-keeping Anticipated**



Transfer to Orbit



- **Nominal Orbit Transfer Plan**
 - **Baseline Launch Date 6/30/2004**
 - **Injection via Delta-II 7425 Into 185 x 36086 km GTO (2.5 Days)**
 - **AKM Firing to +300 km Supersynchronous Orbit (8 Days)**
 - **Two-Burn Maneuver Into GEO (Five Year Mission)**
 - **Depends on OD and Thrusting Accuracy From Supersynchronous Orbit**
 - **May Require Additional Trim Maneuvers**
 - **Disposal Orbit at GEO +300 km Altitude**



Drifting Elliptical Orbit



- **Orbit Is Still “Geosynchronous,” Not Geostationary or Circular**
 - Instead of Circularizing at GEO Altitude, Leave Apogee +300 km
 - Bring Perigee 300 km Below GEO (Eccentricity = 0.007)
 - First-Order Orbit Rates Not Significantly Different
 - Over Five Years, Closest Approach to GEO Band Is >165 km
- **Motivation**
 - Eliminate or Minimize E-W Station-Keeping Propellant
 - Eliminate Need for or Reduce Frequency of E-W Station-Keeping
 - Reduce Fuel Sloshing Which Interferes With Science Goals



Issues With Elliptical Orbit



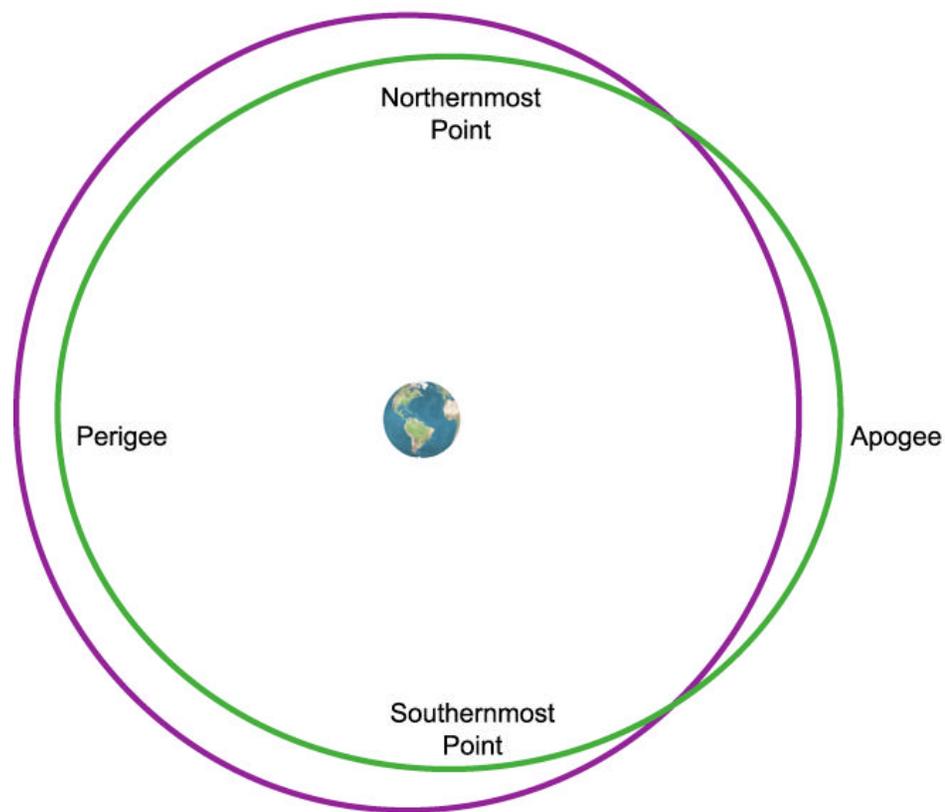
- **At Least 36 Active Commercial GEO Comsats Between 70° and 135° West Longitude**
- **Collision Hazard Due to E-W Drift**
 - FAME Moving at High Relative Speed Compared to Other GEO Satellites
 - We Would Be the Ones Doing Something Different \Rightarrow Burden on Us
 - Over Five Years, Closest Approach to GEO Band Is >165 km
 - Not Expected to Be Problem
- **RF Interference**
 - Will Be Within 1° Band of GEO Belt for 16.6 Minutes Twice Daily
- **RF Link**
 - By Inserting FAME at 105° W, Elevation Over Primary Ground Site (BP) Stays $>7.5^\circ$ Throughout Mission Life (at 109° W)



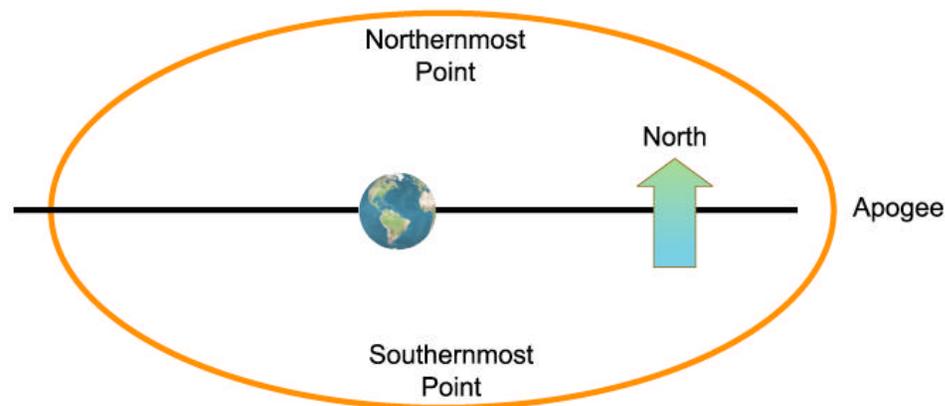
FAME Orbit Views (Not to Scale)



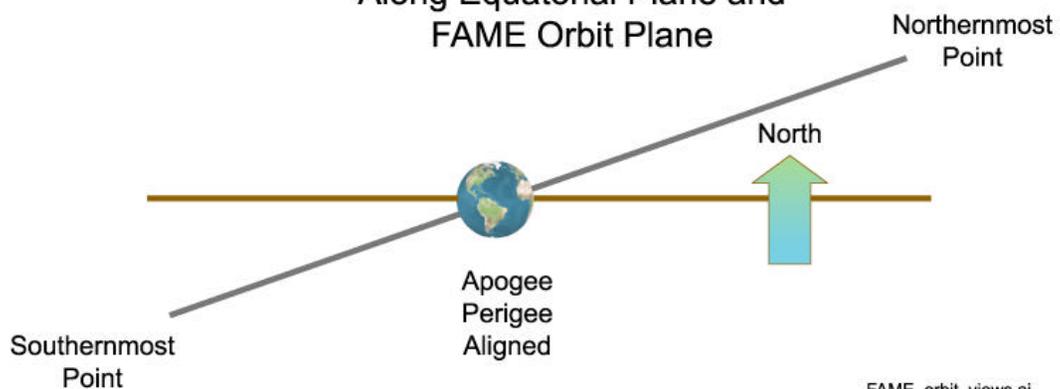
Down From North



Along Equatorial Plane



Along Equatorial Plane and FAME Orbit Plane



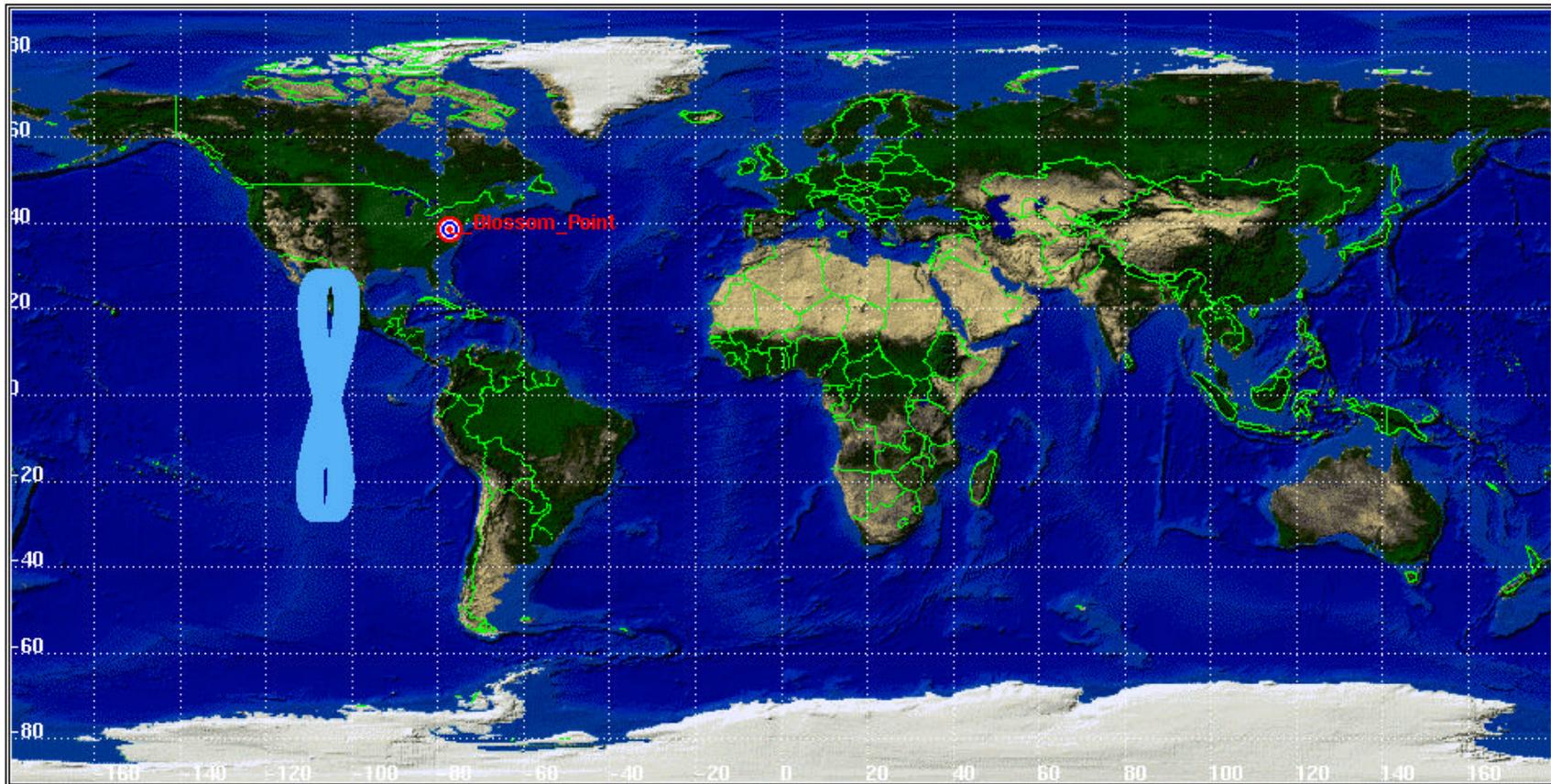
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FAME Ground Track



FAME Ground Track with 105° W LAN at Insertion



Minimum Elevation over Blossom Point = 7.5° (at 109° W LAN)
LAN varies from 103° to 109° over 5 years with 850 day Period.



Pre-Phase B Status

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Pre-Phase B Status (1 of 3)



- **CCD Procurement**
 - **CCD Vendors Were Evaluated (Site Visits)**
 - **CCD SOW Issued**
 - **CCD Vendor Contract Awarded July 2000**
 - **Flight Parts to Be Received at LMMS December 2001**
- **CCD Analysis and Testing**
 - **Evaluate Start/Stop Technology, CCD Centroiding With Different Spectral Responses and Fat Zero Charge Injection Using Test CCDs From Candidate Vendor**
 - **Bought Test CCDs and Test Equipment**
 - **Test Plan Has Been Written**
 - **Test Software in Process**
 - **Tests to Be Performed Late September Thru November**
- **Instrument Requirements Flowdown and Requirements Review**
 - **Science Requirements / Error Budget Have Been Generated**
 - **Further Evaluation Required (Iterative Process)**



Pre-Phase B Status (2 of 3)



- **Opto-Thermal-Mechanical Stability Study**
 - **Currently in Process**
- **Telescope PSF Trade Study**
 - **Preliminary Analysis Has Been Conducted**
- **ACS/Solar Precession Analysis**
 - **NRL and USNO Have Continued CSR Solar Precession Analysis**
 - **Determined Initial Requirements for Data Analysis/Spacecraft Subsystems**
 - **Further Analysis Required**



Pre-Phase B Status (3 of 3)



- **Orbit Design**
 - Orbit Design Updated to Eliminate E-W Stationkeeping
 - Slightly Elliptical Orbit Chosen at 105 Degrees West (+/- 2 Degrees)
 - Initial RF License Filing Submitted to NASA-GSFC
- **Orbit Determination**
 - Further Analysis Conducted for 1 cm/sec Velocity Knowledge Requirement (to Remove Aberration Error)
 - Analysis Indicates That a Combination of Range and Range Rate Measurements Will Meet This Requirement
- **Data Analysis Pipeline**
 - Evaluating Data Reduction Algorithms (3D Spiral vs. the Great Circle Reduction [Hipparcos])