FAME Mechanisms

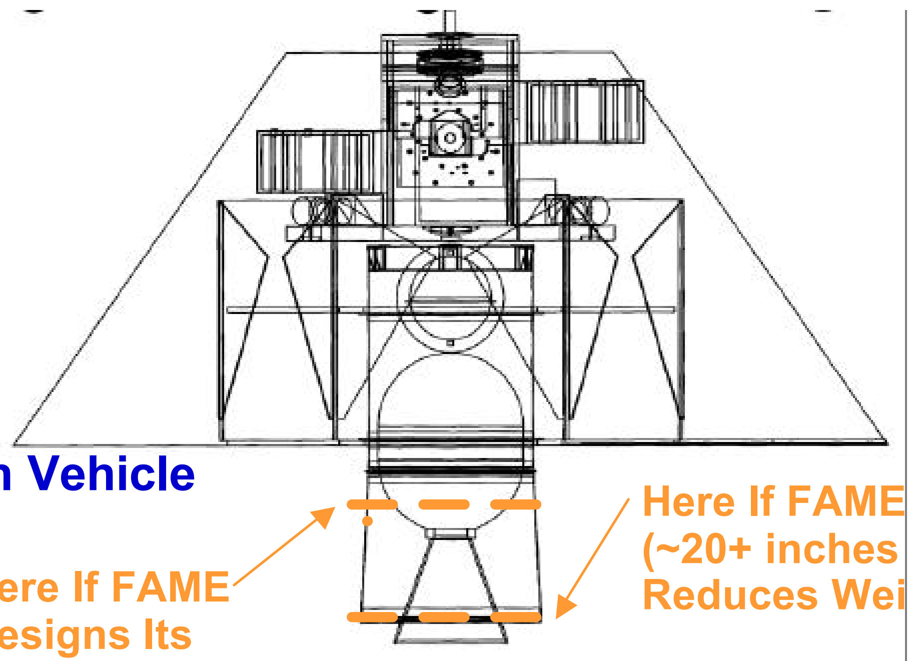
Steve Koss / Mike Hurley
NRL
202-767-0696
skoss@space.nrl.navy.mil

FAME Mechanisms Systems

- Spacecraft/Launch Vehicle Separation System
- Satellite/Solid Rocket Separation System
- Star Tracker Cover System
- CG Trim Mass System
- Sun Shield Deployment System
- Radiation Trim Tab System
- TBD Solid Rocket Hole Cover
- TBD Main Instrument Cover System

Spacecraft/Launch Vehicle Separation System
Top Level Requirements

1. Structurally Hold the Spacecraft to the Launch Vehicle During Launch
2. Provided a Highly Reliable Separation of the Spacecraft From the LV
3. Survive & Operate in All Field & Launch Environments
4. Accommodate Required LV ICD Constraints
5. Design & Installation Procedure Must Be Compatibility With Range Safety Requirements



Spacecraft/Launch Vehicle Separation Plane

Here If FAME Designs Its Own Clamp

Here If FAME Uses Delta II PAF Clamp (~20+ inches lower so adds ~40lb so Reduces Weight to Orbit by ~40 lb)

Spacecraft/Launch Vehicle Separation System Derived Requirements (1 of 2)

- 1. Structurally Hold the Spacecraft to the Launch Vehicle During Launch
  - 1a. Survive Launch Loads of 3.2* g's Axial Tension & +/-3 g's Lateral (Loads From Delta II Handbook *Added 3.0 g's)
  - 1b. Assure a Linear Separation Joint and No Gapping
- 2. Provided a Highly Reliable Separation of the Spacecraft From the LV
  - 2a. No Contact Between the SC & LV During Separation With Initial LV Rates of 0.2 deg/s (TBR)
    - 2a1. Surrounding Mechanisms, Structure, & Blankets Must Be Designed to Minimize Any Possibility of Grabbing or Catching
  - 2b. Assure No Recontact by Providing at Least 1 ft/sec Delta V Between the Spacecraft & Launch Vehicle at Separation
  - 2c. Redundant Firing Circuits
  - 2d. Redundant Release Devices or Redundant Initiators As Appropriate to Provide the Most Reliable Design
  - 2e. Use Only Robust/reliable Design Techniques for Separation
    - 2e1. Separating Surfaces Must Be of Compatible Materials & Have Appropriate Finishes and/or Lubricants
      - 2e1a. Provide an Electrically Conductive Path Across the Separation Joint
    - 2e2. No Binding Angles <20 Deg. Between Separating Surfaces
    - 2e3. All Wire Harnesses Must Have Adequate Play for Moving Components

Spacecraft/Launch Vehicle Separation System Derived Requirements (2 of 2)

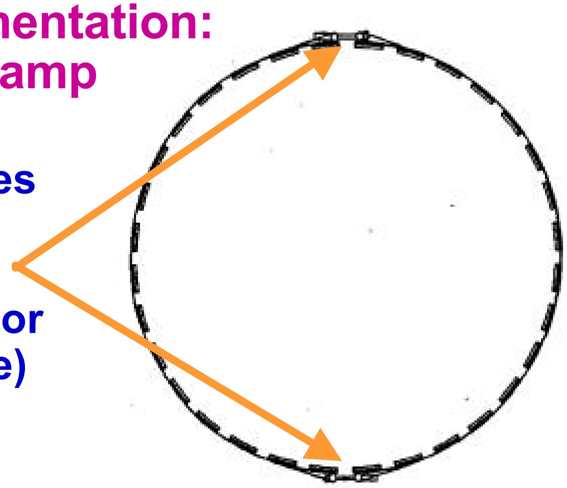
- **3. Survive & Operate in All Field & Launch Environments**
  - **3A. Survive & Operate In a Temperature Range of +10C to +30C (TBR)**
  - **3B. Survive & Operate In a Controlled Moisture Environment of 30-70% Humidity (TBR)**
  - **3C. Survive LV Pressure Decay Rate XX psi/sec & Operate In Hard Vacuum <10^{-5} torr**
  - **3D. Survive & Operate in Lab Environment – Temp & Humidity from 3A & 3B Plus Operate in 1 Atmosphere**
- **4. Accommodate Required LV ICD Constraints**
  - **4A. Mate to TBD LV Bolt Pattern**
  - **4B. TBD LV Firing Circuit Interfaces/Limitations**
- **5. Design & Installation Procedure Compatibility with Range Safety Requirements**
  - **5A. Two Fault Tolerant Ordnance/Mechanism Firing Design**
    - **5A1. Implement Safe/Arm Plug, Enable Command, & Fire Command to Fire**
  - **5B. Restrain All Mechanism Parts After Separation (No Parts Can be Released Into Space)**
  - **5C. Provide Installation Procedure for Range Safety Review**
    - **5C1. Use Non-Flammable Materials & Tools**
  - **5D. Provide Material Safety Data Sheets for Any Ordnance Used**

Major Trade: What Type Separation System to Use

	Marman Clamp	Separation Nuts/Joints (4)	Separation Nuts/Joints (8)
Load Path	Excellent	Poor	Fair
Weight	Good	Poor	Poor
Redundancy	Excellent	Good	Good
Required Ordnance	Good (2 - 4)	Fair (8)	Poor (16)

Selected Implementation: Marman Clamp

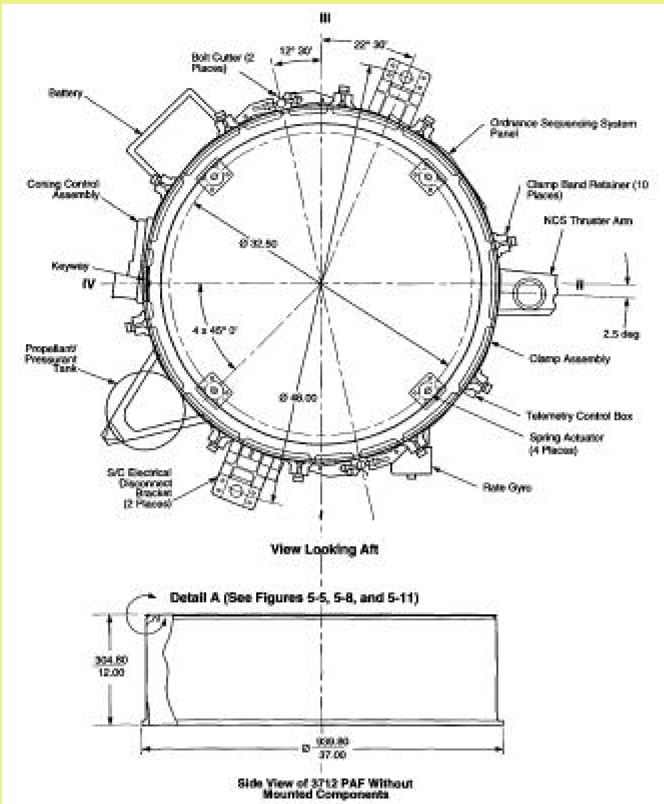
Separation Devices in Two Places (Clamp will Separate if Either or Both Devices Fire)



- Best Load Path (Cylinder to Cylinder)
- Significantly Lighter Than a 4 or 8 Separation Nut/Joint Systems
  - WRT Mechanisms Weight, Structure Weight, & Ordnance System Weight
- Reduces Required Ordnance From 16 Lines to 4 Lines (Maximum)
- Inherently Redundant

Major Trade: Use Delta Clamp or Custom FAME Clamp (1 of 2)

Drwg of Delta's 3712 Payload Adapter Fitting

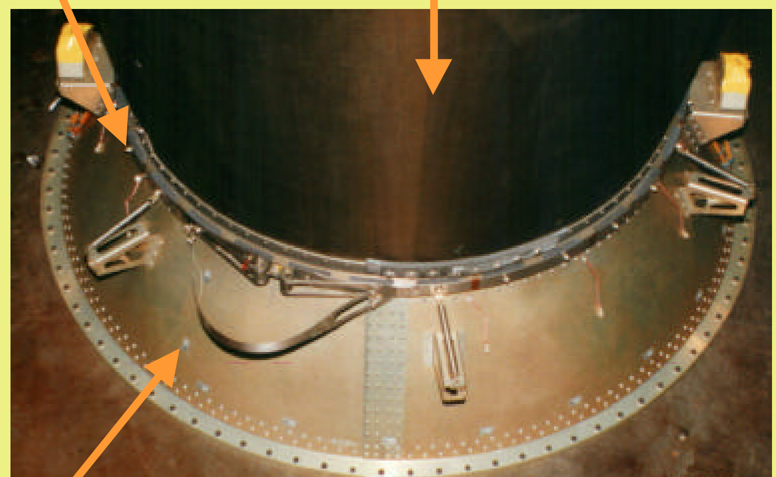


- FAME Would Build the "Top" Ring of This Marman Clamp System Into the Spacecraft Interstage
- Note: The "Bottom" Ring Is an Integral Part of This PAF Assy

Example of Custom FAME Clamp Configuration

Clamp

Interstage to the Spacecraft



LV Adapter

(Clementine Marman Clamp Shown)

- FAME would Build the "Top" Ring of this Marman Clamp System into the Spacecraft Interstage & Provide an Adapter with the "Bottom" Ring & with a Bolt Pattern Interface to the Launch Vehicle

Major Trade: Use Delta Clamp or Custom FAME Clamp (2 of 2)

	Delta 3712 PAF Marman Clamp	Custom FAME Marman Clamp
Weight	Fair	Good (Saves ~40 lb)
Cost	Excellent (Comes w/ Delta Cost)	Poor (Est. ~$500k + TBD Delta PAF Modification Costs)
All Other Design Features & Benefits (Reliability, Functionality, etc)	Same	Same

- Specific Implementation Recommendation
  - Baseline Delta II PAF 3712 (Type B or C) Marman Clamp
    - Note: B & C Ring Types Need Further Investigating – However C Is Lighter and Is Currently Preferred
  - If at PDR Weight to GEO Is Critical Can Gain About 40 Lb by Designing a FAME Specific Marman Clamp and Changing the Delta PAF Interface to a Bolt Pattern

Critical Design Calculations (1 of 2)

- At Delta II 3712 Marman Clamp Interface
  - Line Load N= 295 lb/in
  - Required Preload= 4000 lb (3600 lb Min to 4800 lb Max)
  - Given
    - Loads 3.2* g's Axial Tension, +/- 3 g's Lateral (From Delta II Hdbk *Added 3.0 g's)
    - Weight = 2290 lb at 49.1 Inches Above Separation Plane
    - Shoe & Ring Angle= 20 Degrees
    - +/-20% Preload Variation (No Gages)
    - Includes a Program Maturity Factor of 2.0 Applied to the Line Load to Account for Typical Weight & Loads Growth
      - Use 2.0 Thru SRR, 1.75 at PDR, 1.5 at CDR, 1.1 Post Coupled Loads Analysis & CDR Weight
  - Results Show Delta II PAF 3712 (Type B or C) Marman Clamp Will Support the FAME Loads W/ a FS = 5700/4800 = 1.2 on Preload
    - PAF 3712 (B or C) Clamp Maximum Preload Is 5700 lb From Delta II Hdbk

Critical Design Calculations (2 of 2)

- At FAME Custom Clamp Interface (-12 in From Z=0 Datum)
  – Line Load N = 231 lb/in
  – Required Preload = 3100 lb (2500 lb Min to 3700 lb Max)
  – Given
    - Loads 3.2* g's Axial Tension, +/- 3 g's Lateral (From Delta II Hdbk *Added 3.0g's)
    - Weight = 2290 lb at 30.1 Inches Above the Separation Plane
    - Shoe & Ring Angle = 20 Degrees
    - +/-20% Preload Variation (No Gages)
    - Includes a Program Maturity Factor of 2.0 Applied to the Line Load to Account for Typical Weight & Loads Growth
      - Use 2.0 Thru SRR, 1.75 at PDR, 1.5 at CDR, 1.1 Post Coupled Loads Analysis & CDR Weight
  – Results Show Clementine Marman Clamp Design Will Probably Support the FAME Loads (Clementine Qualified to N = 240 lb/in and a Preload of 3600 lb +/- 400 lb)

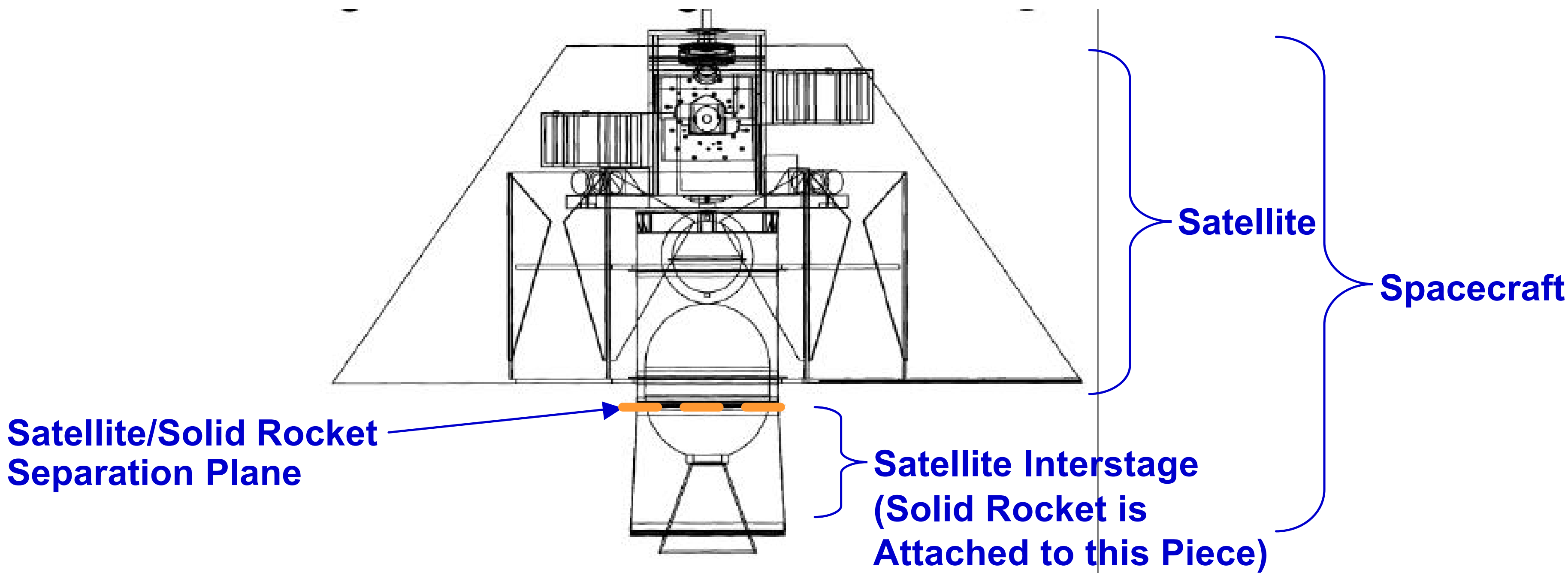
Spacecraft/Launch Vehicle Separation System

- **Long Lead Items**
  - **N/A : Clamp Comes With Delta III**

- **Issues**
  - **No Foreseen Issues**

Satellite/Solid Rocket Separation System
Top Level Requirements

1. Structurally Hold the Satellite to the Solid Rocket During Launch and Orbit Transfer Maneuvers
2. Provided a Highly Reliable Separation of the Satellite From the Solid Rocket
3. Survive & Operate in All Field, Launch, & Orbit Transfer Environments
4. Accommodate Required Satellite Structure – e.g. Sun Shield
5. Design & Installation Procedure Must Be Compatibility With Range Safety Requirements



Satellite/Solid Rocket Separation System Derived Requirements (1 of 2)

- **1. Structurally Hold the Satellite to the Solid Rocket During Launch and Orbit Transfer Maneuvers**
  - **1A. Survive Launch Loads of 3.2* g's Axial Tension & +/-3 g's Lateral (Loads From Delta II Handbook *Added 3.0 g's) & TBD Circularization Burn Loads**
  - **1B. Assure a Linear Separation Joint and No Gapping**
- **2. Provided a Highly Reliable Separation of the Satellite From the Solid Rocket**
  - **2A. No Contact Between the Satellite & the Solid Rocket During Separation With Initial LV Tip-off Rates of 0.2 Deg/s (TBR)**
    - **2A1. Surrounding Mechanisms, Structure, & Blankets Must Be Designed to Minimize Any Possibility of Grabbing or Catching**
  - **2B. Assure No Recontact by Providing at Least 1 ft/sec Delta V Between the Satellite & the Solid Rocket at Separation**
  - **2C. Redundant Firing Circuits**
  - **2D. Redundant Release Devices OR Redundant Initiators As Appropriate to Provide the Most Reliable Design**
  - **2E. Use Only Robust/reliable Design Techniques for Separation**
    - **2E1. Separating Surfaces Must Be of Compatible Materials & Have Appropriate Finishes And/or Lubricants**
      - **2E1a. Provide an Electrically Conductive Path Across the Separation Joint**
    - **2E2. No Binding Angles <20 Degrees Between Separating Surfaces**
    - **2E3. All Wire Harnesses Must Have Adequate Play for Moving Components**

Satellite/Solid Rocket Separation System Derived Requirements (2 of 2)

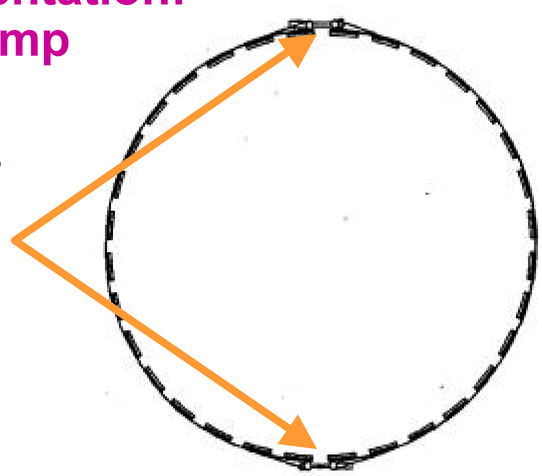
- 3. Survive & Operate in All Field, Launch, & Orbit Transfer Environments
  - 3A. Survive & Operate In a Temperature Range of –20 C to +50 C (TBR)
  - 3B. Survive & Operate In a Controlled Moisture Environment of 30-70% Humidity (TBR)
  - 3C. Survive LV Pressure Decay Rate XX psi/sec & Operate In Hard Vacuum $<10^{-5}$ torr
  - 3D. Survive & Operate in Lab Environment – Temp & Humidity From 3A & 3B Plus Operate in 1 Atmosphere
- 4. Accommodate Required Satellite Structure – e.g. Sun Shield
  - 4A. Design, Separation, & Particularly Installation Must Accommodate Some Fairly Tight Space Limitations Due to Surrounding Structure
  - 4B. TBD Firing Circuit Interfaces/Limitations With TBD FAME Ordnance Box
- 5. Design & Installation Procedure Compatibility With Range Safety Requirements
  - 5A. Two Fault Tolerant Ordnance/mechanism Firing Design
    - 5A1. Implement Safe/arm Plug, Enable Command, & Fire Command to Fire
  - 5B. Restrain All Mechanism Parts After Separation (No Parts Can Be Released Into Space)
  - 5C. Provide Installation Procedure for Range Safety Review
    - 5C1. Use Non-flammable Materials & Tools
  - 5D. Provide Material Safety Data Sheets for Any Ordnance Used

Major Trade: What Type Separation System to Use

	Marman Clamp	Separation Nuts/Joints (4)	Separation Nuts/Joints (8)
Load Path	Excellent	Poor	Fair
Weight	Good	Poor	Poor
Redundancy	Excellent	Good	Good
Required Ordnance	Good (2 - 4)	Fair (8)	Poor (16)

Selected Implementation: Marman Clamp

Separation Devices in Two Places (Clamp Will Separate If Either or Both Devices Fire)

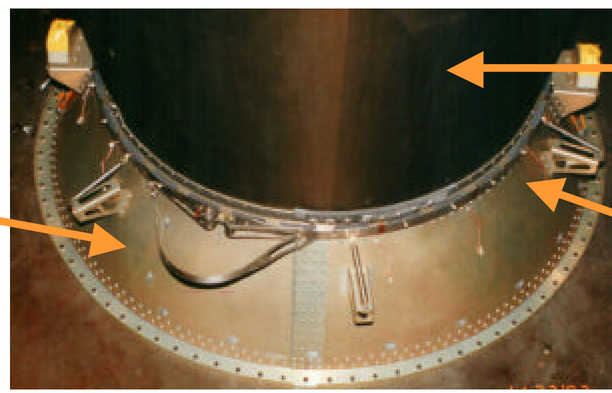


- Best Load Path (Cylinder to Cylinder)
- Significantly Lighter Than a 4 or 8 Separation Nut/joint Systems
  - WRT Mechanisms Weight, Structure Weight, & Ordnance System Weight
- Reduces Required Ordnance From 16 Lines to 4 Lines (Maximum)
- Inherently Redundant

Critical Design Calculations

- At Satellite / Solid Rocket Separation Plane (Z=0 In)
  - Line Load N = 132 lb/in
  - Required Preload = 1800 lb (1400 lb Min to 2200 lb Max)
  - Given
    - Loads 3.2* g's Axial Tension, +/- 3 g's Lateral (From Delta II Hdbk *Added 3.0 g's)
    - Weight = 1240 lb at 34.1 Inches Above Separation Plane
    - Shoe & Ring Angle = 20 Degrees
    - +/-20% Preload Variation (No Gages)
    - Includes a Program Maturity Factor of 2.0 Applied to the Line Load to Account for Typical Weight & Loads Growth
      - Use 2.0 Thru SRR, 1.75 at PDR, 1.5 at CDR, 1.1 Post Coupled Loads Analysis & CDR Weight
  - Results Show the Clementine Marman Clamp Design WILL Support the FAME Loads (Clementine Qualified to N = 240 lb/in and a Preload of 3600 lb +/- 400 lb)

- For FAME This Will Be a Satellite Interstage
- Note: the SOLID ROCKET Will Be Attached to This Side



For FAME This Will Be Part of the Satellite Structure

Clamp

Clementine Marman Clamp Shown

Satellite/Solid Rocket Separation System

- Long Lead Items
  - Sepbolt With Ordnance 9-12 Months (Quote Coming)
    - Hi-shear SC1005-4D Clamp Separator, Part # 9362693-2
    - Power Cartridge PC72-003, Part # 939714-003

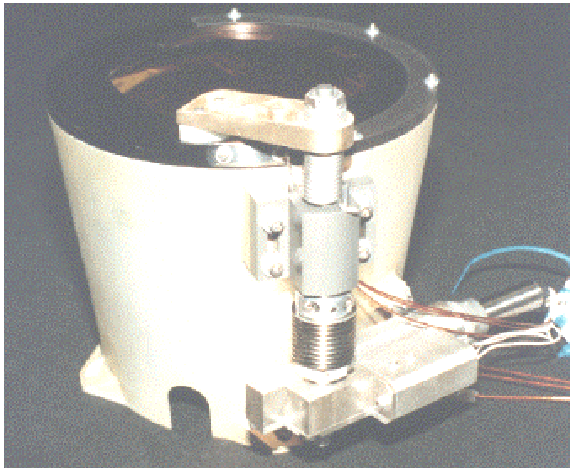
- Issues
  - None

Star Tracker Cover System
Top Level & Derived Requirements

- 1. Protect Star Trackers From Debris Contamination During Field Ops, Launch & During the Solid Rocket Burn
  - 1A. Prevent 0.001 in and Greater Diameter Particles and From Entering the Seal
  - 1B. Multi-Use
    - Is This A Requirement? (e.g. Are Star Trackers Used to Determine Attitude Before the GTO or Circularization Burn? Or Only Once in Geo Orbit?)
    - 1B1. Required Life Cycles < or = 3 (Expect Only 2 or 3 Cycles Required e.g. Do NOT Need to Cover Camera During Mono-prop Hydrazine Thruster Burns)
- 2. Highly Reliable Operation
  - 2A. Use Redundant Electrical Actuation Circuits
  - 2B. Use High Force/Torque Opening Margins
  - 2C. Use Appropriate Materials & Lubricates for Sliding & Separating Parts
  - 2D. Perform Rigorous Qualification & Acceptance Testing
- 3. Survive in Ground, Launch, & Space Environments; Operate in the Ground & Space Environments
  - 3A. Survive TBD Component Vibration Spec.
  - 3B. Survive & Operate in -40 to +60 C TBR Temp. Env.
  - 3C. Survive & Operate in a Controlled Moisture Environment of 30-70% Humidity (TBR)
  - 3D. Survive LV Pressure Decay Rate XX psi/sec & Operate in Hard Vacuum <10^{-5} torr
  - 3E. Survive & Operate in Lab Environment – Temp & Humidity From 3A & 3B Plus Operate in 1 Atmosphere

Star Tracker Cover System

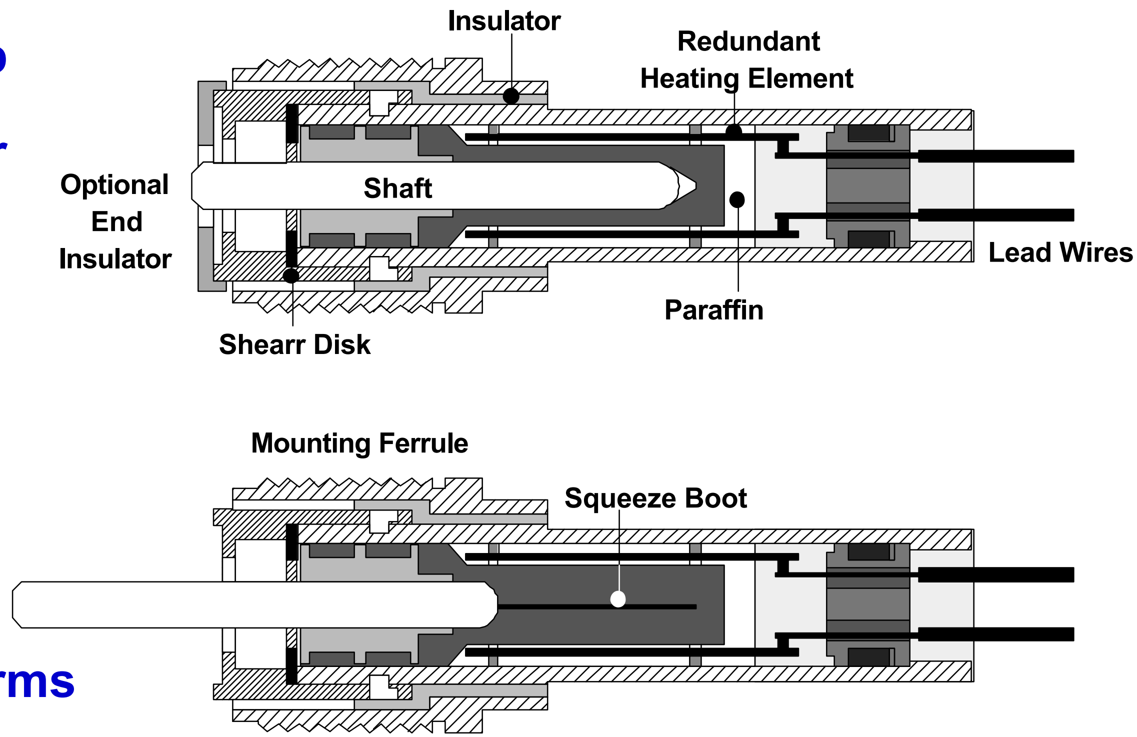
- Design Approach
  - Anticipate a Paraffin Actuated Cover With a Binary Latch
- Trade Studies
  - Actuator Types
  - Seal Geometry
- Long Lead Components
  - Actuator - Paraffin Actuators Typically Less Than 6 Months
  - Binary Latch – 6-9 Months
- Issues
  - Are These Covers Required?
    - If So, When Are the Star Tracker Cameras Used? Specifically Are They Used in LEO, GTO, or Only in GEO?
  - No Technical or Schedule Issues Anticipated



Clementine Star Tracker Cover
- Paraffin Actuated
- Binary Latch Mechanism to Hold Cover Open

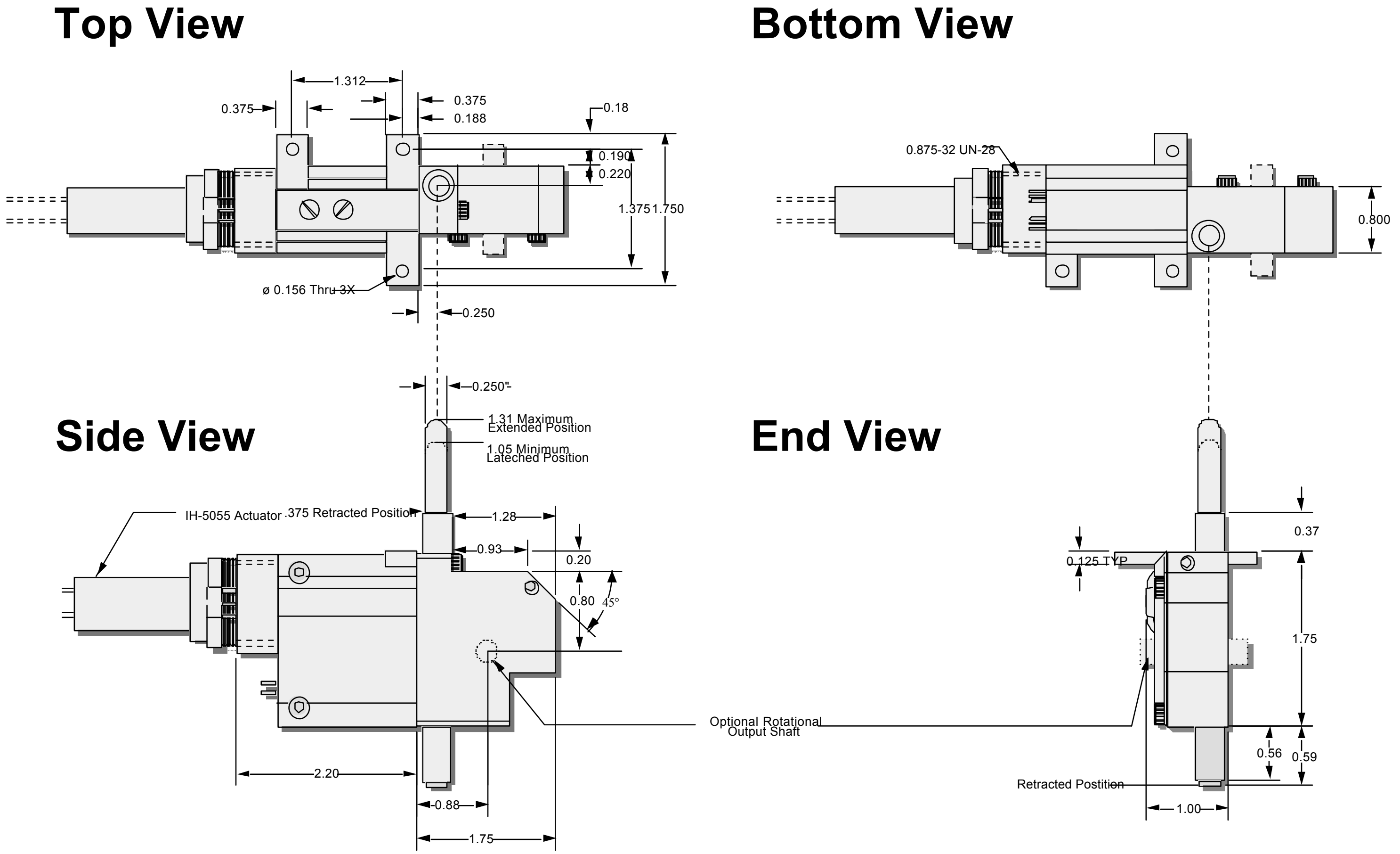
Star Tracker Cover System: Actuator Specifications

- Low Weight: Typically 0.125 lb
- Power Requirements: 10 W for 120 Sec
- High Reliability:
  - One Moving Part
  - Redundant Heaters
- Robust to Environments
  - Vibration Qualed to XXX Grms
  - Operates From -40C to +65C (Check Low #)
  - Will Not Self Actuate Up to 80C



Paraffin Actuator

Star Tracker Cover System:
StarSys RF-1035 Rotary Binary Latch



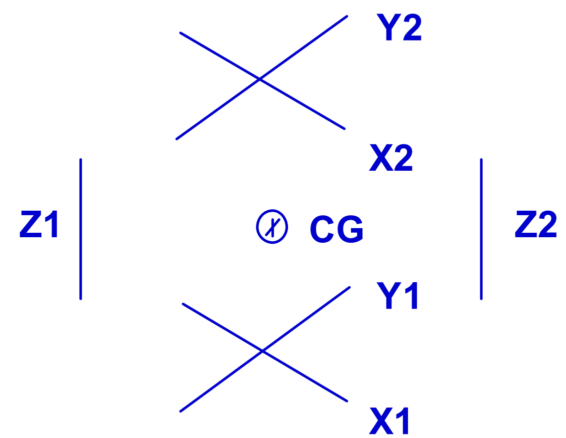
STC-Rot Bin Latch

CG Trim Mass System
Top Level & Derived Requirements

- 1. Adjust CG in the Radial Axis to +/- 1mm (+/-0.707 Mm in X & Y Axis) and to +/-1mm (TBR) in the Z Axis (Spin Axis) of a Desired Location Throughout the Mission
  - 1A. Mass Position to 0.1 mm (TBR)
  - 1B. Move TBD Amount of Mass Over TBD Stroke
- 2. Align the Spin Axis to +/- 30 Arcsec WRT the Geometrical Z axis
  - 2A. Adjust 3 (TBR) Products of Inertia to TBD Maximum Values
    - 2A1. Requires AT LEAST 2 CG Trim Masses Per Axis (Config. Being Reviewed)
  - 2B. Mass Position to 0.5 mm (TBR)
  - 2C. Move TBD Amount of Mass Over TBD Stroke
- 3. Highly Reliable Operation Throughout Mission Life
  - 3A. 3 yr on Orbit, TBD Cycle Life (Operate Once Every TBD Months)
  - 3B. Compensate for Propellant Mass Loss
    - 3B1. TBD ### of Adjustments Depending on Prop Use Profile and CG & Spin Axis Tolerances
- 4. Minimize Operational Impact on Mission
  - 4A. TBD Jitter Input Requirement & TBD Max Adjustment Speed Requirement
  - 4B. Command From Ground Based On Determination of On-Orbit Wobble
- 5. Survive in Ground, Launch, & Space Environments; Operate in the Ground & Space Environments
  - 5A. Survive TBD Component Vibration Spec.
  - 5B. Survive & Operate in -20 to +60 C TBR Temp. Env.
  - 5C. Survive & Operate In a Controlled Moisture Environment of 30-70% Humidity (TBR)
  - 5D. Survive LV Pressure Decay Rate XX psi/sec & Operate In Hard Vacuum $<10^{-5}$ torr
  - 5E. Survive & Operate in Lab Environment – Temp & Humidity From 3A & 3B Plus Operate in 1 Atmosphere

CG Trim Mass System

- Design Approach
  - 6 Trim Balance Mass Leadscrews (X,Y,& Z Axes In 2 Planes Each)
  - Trim Balance Mechanism Consists of Balance Mass Whose Position Is Adjusted by Stepper Motor Driven Leadscrews
  - Heritage Mechanism Designs Available
  - Use Same Actuator for All 6 Trim Mass Leadscrews
  - Use Only 2 Motor Controllers & Switch Between Pairs of Motors to Drive
    - Allows Up to 2 Motors to Be Driven Simultaneously and Can Still Drive Each Separately
- Trade Studies
  - Configuration / Orientations of Trim Mass Mechanisms
  - Specific Stepper Motor Actuator
- Long Lead Components
  - Actuator – Stepper Motor 6-9 Months
- Issues
  - Need Improved Requirements Definition & Verification That 6 Trim Masses in Configuration Shown Is Adequate



Baseline Configuration / Orientations

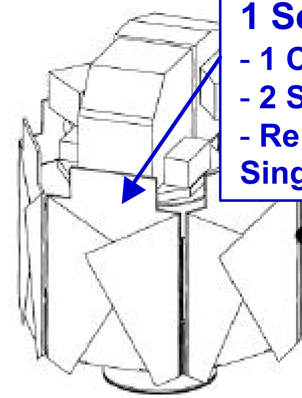
Stepper Motor With Lead Screw

Sun Shield Deployment System (SSDS) Top Level & Derived Requirements

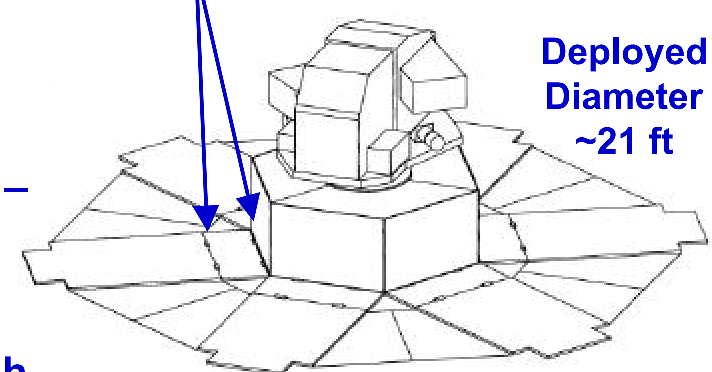
- 1. Deploy Sun Shield to Protect Primary Fame Instrument from the Sun
  - 1A. 45 Degree FOV Sun Protection Requires a Specific Deployed Geometry
- 2. Highly Reliable Deployment
  - 2A. Use Redundant Electrical Actuation Circuits
  - 2B. Use High Force/Torque Deployment Margins
  - 2C. Use Appropriate Materials & Lubricates for Sliding & Separating Parts
  - 2D. Perform Rigorous Qualification & Acceptance Testing
- 3. Assure Deployed Sun Shield Surface is Compatible With ACS Radiation Spin & Precession Scheme
  - 3A. 15 Hz (TBR-from 1/10 of 1.56 s Integration Time) Minimum Natural Frequency Rqmts (Mech. & Strct. Rqmt)
  - 3B. Deploy to & Maintain Flatness of 0.200 inches (TBR) Over Entire Surface (Mech, Strct, & TCS Rqmt)
  - 3B1. Variation of 0.200 in per 6 ft (0.050 in Deployment, 0.030 in Structural Manf, 0.120 in Thermal)
  - 3C. Minimize Non-Flat Features (Mech. & Strct. Rqmt)
  - 3C1. Maximum Height Discontinuity of 0.25 inches (TBR) Across Entire Surface (Mech. & Strct. Rqmt)
  - 3C2. Maximize Symmetry of Disturbing Features (Mech. & Strct. Rqmt)
- 4. Survive in Ground, Launch, & Space Environments; Operate in the Ground & Space Environments
  - 4A. Survive TBD Component Vibration Spec.
  - 4B. Survive & Operate in –20 to +60 C TBR Temp. Env.
  - 4C. Survive & Operate In a Controlled Moisture Environment of 30-70% Humidity (TBR)
  - 4D. Survive LV Pressure Decay Rate XX psi/sec & Operate In Hard Vacuum <10^{-5} torr
  - 4E. Survive & Operate in Lab Environment – Temp & Humidity from 3A & 3B Plus Operate in 1 Atmosphere

Sun Shield Deployment System (SSDS)

- **Design Approach**
  - Deploy in 6 Segments
    - Each Segment Contains a Honeycomb Center Panel With 2 Sheet Metal or Honeycomb Side Panels
  - A Single Frangibolt Releases Each Segment
  - Spring Driven Hinges Deploy & Latch Side Panels While 1 or 2 Spring Driven Hinges Deploy & Latch the Center Panel of Each Segment
    - Single Hinge Greatly Preferred (Pending 10 ft LV Fairing Decision)
- **Trade Studies**
  - One or Two Hinge System
  - Release Device
  - Segmented Panel System Verses Tension Mesh Type Deployment System
- **Long Lead Components**
  - Release Device – Frangibolts 6 Months
- **Issues**
  - Need to Verify the Baseline Design Approach Is Capable of Meeting the ACS Flatness Requirements – It Is Fairly Likely It Will Not
    - If Not Then a Much More Complex, “One Piece”, Tensioned Web Type System Will Be Required
      - The Design & Testing Would Both Become Much More Complex



Sun Shield Stowed



Sun Shield Deployed

Sun Shield Deployment System (SSDS) Deployment System Trade Study

	Segmented, Honeycomb Panel Based System	"One Piece" Tensioned Web System
Ability to Block Sun	Excellent	Fair
Ability to Meet ACS Flatness Rqmts	Good/Poor (TBD)	Good
Weight	Good	Good
Simultaneous Release	NOT Required	Required
Design Simplicity	Excellent	Fair
Testing Simplicity	Excellent	Poor

- **Segmented, Honeycomb Panel Based System Is Baselined Pending Verification That It Can Meet the ACS Flatness Requirements**

Sun Shield Deployment System (SSDS) Release Device Trade Study

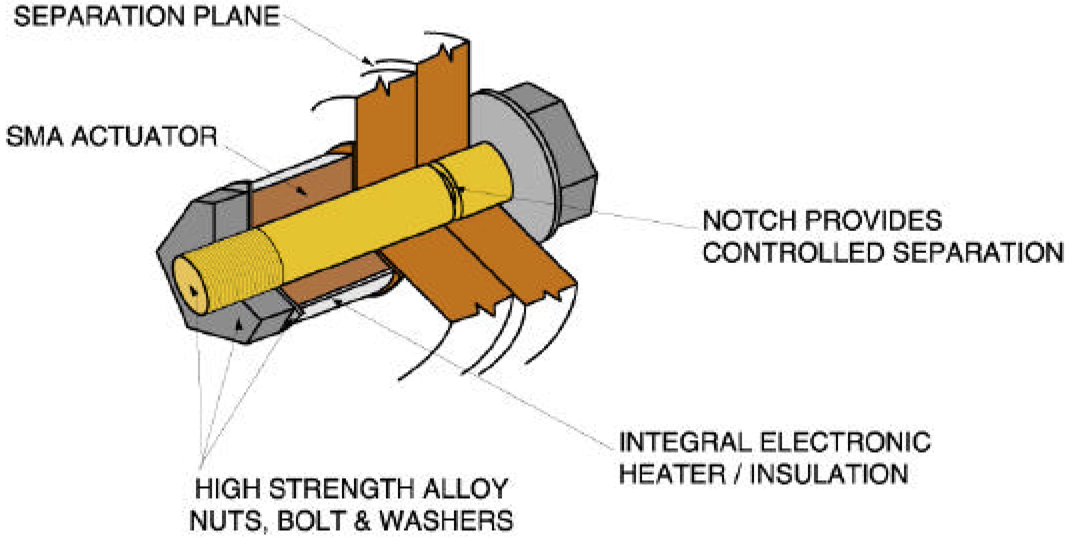
	Frangibolts	Bolt Cutters	Separation Nuts
Weight	Excellent	Good	Poor
Redundancy	Excellent	Good	Good
Safety	Excellent	Fair	Fair
Power	Poor (90 W For 30 sec)	Good (5 A for 2 ms)	Good (5 A For 2 ms)
Shock	Fair	Good	Fair
Fast-Simultaneous Release	NO	Yes	Yes

- Frangibolts Are the Baselined Release Device
  - Pending Confirmation That Design Will NOT Require Simultaneous Release

Sun Shield Deployment System (SSDS)

Frangibolt Overview

- **Description:**
  - Shape Memory Alloy Actuator to Break Bolt In Tension
  - 28 Vdc Heater Drives Actuator Which Elongates When Heated (90 W for 30 sec)
  - Notched Bolt Stretches Until It Fails At Notch (Controlled Breakage)
- **Advantages:**
  - Light Weight: Actuator .05 lb
- **Excellent Reliability**
  - Redundant Heaters
  - No Sliding Friction
- **Moderate Pyroshock**
- **Safer Design Due to Elimination of Explosives**
- **Not Sensitive to EMI - Can Use Unshielded Wiring**

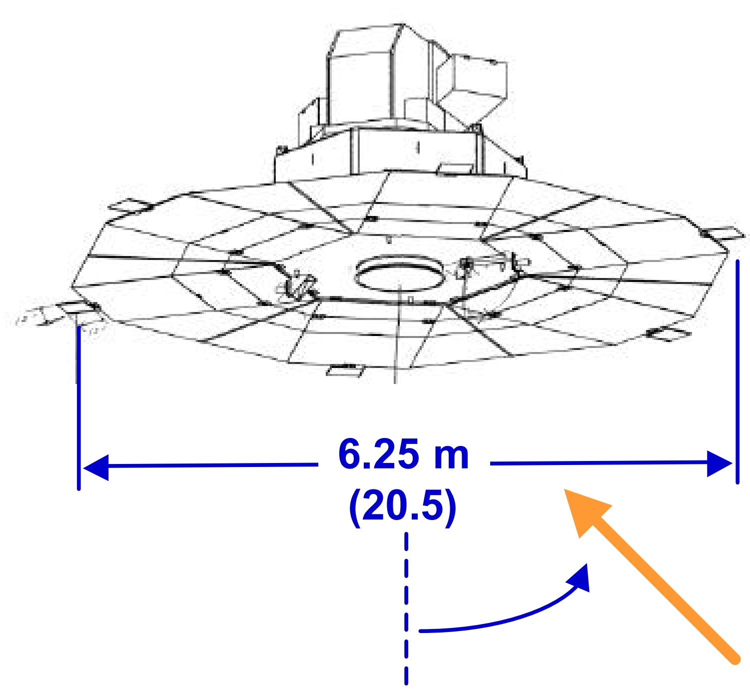


Trim Tab System
Top Level & Derived Requirements

- 1. Compensate for Torque Imbalances about the Axes Perpendicular to the Sun's Rays Up to 1E-6 N*m (TBR)
  - 1A. Rotate Each Trim Tabs Perpendicular & Parallel to the Sun to Within 0.5 deg (TBR)
  - 1B. Adjust All Trim Tabs Up to 10 Degrees (TBR) Within 2 Minutes (1/20 of Spin Rate) So As to "Instantaneous" Affect the Radiation Balance Within a Single Spin Revolution
- 2. Use 6 Trim Tabs because of the Vehicle's Geometry
  - 2A. Use Same Motor for All 6 Trim Radiation Trim Tabs & As a Goal Also Use the Same Motor Used on the Trim Mass System
- 3. TBD Provide Spin Adjustment (Trimming)
  - IF NEEDED It May Be More Effective to Use an Inertia Adjustment Via CG Trim System
- 4. Highly Reliable Operation Throughout Mission Life
  - 4A. 3 yr On Orbit, TBD Cycle Life (Operate Once Every TBD Months)
- 5. Minimize Operational Impact on Mission
  - 5A. TBD Jitter Input Requirement & TBD Max Adjustment Speed Requirement Based on Jitter
  - 5B. Command From Ground Based On Need Adjustments Determined on the Ground
- 6. Survive in Ground, Launch, & Space Environments; Operate in the Ground & Space Environments
  - 6A. Survive TBD Component Vibration Spec.
  - 6B. Survive & Operate in -40 to +80 C TBR Temperature Environment
  - 6C. Survive & Operate In a Controlled Moisture Environment of 30-70% Humidity (TBR)
  - 6D. Survive LV Pressure Decay Rate XX psi/sec & Operate In Hard Vacuum <10^{-5} torr
  - 6E. Survive & Operate in Lab Environment – Temp & Humidity From 3A & 3B Plus Operate in 1 Atmosphere

Trim Tab System

- Design Approach
  - 6 Trim Tabs Each Driven by Stepper Motors
  - Heritage Stepper Motor Designs Available
  - Use Same Actuator for All 6 Trim Tabs
  - Use Only 1 Fully Redundant Motor Controller & Switch Between Motors to Drive Each Tab
  - Each Trim Tab Area Is 0.10 M^2 (Provides 3.77E-6 N*m Maximum Torque for 1 Pair)
- Trade Studies
  - Whether to Use Motor to Move the Tabs or to Use Heaters and Create Thermal Thrusters
  - Specific Stepper Motor Actuator
- Long Lead Components
  - Actuator – Stepper Motor 6-9 Months
- Issues
  - Need Improved Requirements Definition
    - Especially If Trim Tabs Are Also to Perform Spin Adjustment



Sun at 45 Degree Angle to the Sun Shield

Trim Tab System

- Motor Driven Trim Tabs Verses Thermal Thrusters Trade Study
- Currently NO Baseline Is Selected
  - From a Mechanisms Point-of-view Prefer Thermal Thrusters If Heater Power Is Available & No Major Thermal Concerns Are Foreseen

	Motor Driven Trim Tabs	Thermal Thrusters
Design Simplicity	Fair (6 Motors & 1 Controller)	Excellent (Heaters & Relays)
Power Required	Excellent (None Once Adjusted)	Poor (~270 W x 1.5 to 2 for Max. Equival. Torque, Can Reduce by Increasing Moment Arm)
Temperature Issues	Excellent (Minimal)	Poor (Need T= 200 C) (Can Be Reduced by Increasing Tab Size)
Thermal Torque Issues	Unknown	Unknown
Weight	Good	Excellent
Testing Simplicity	Good	Excellent

TBD Solid Rocket Hole Cover

- Top Level Requirements
  - Cover Hole Left by Solid Rocket to Prevent Optical/Radiation Torque Disturbances From This Source
  - Cover Must Be Flat to TBD in/in, Have TBD Optical Properties
  - Highly Reliable
- Issues
  - Need to Verify If This Is Needed

TBD Main Instrument Cover System

- Is LM Doing This?
- Do We Need to Provide Power to Actuate It?