Design Analysis of A Scientific Balloon Instrument Support Structure (ISS)

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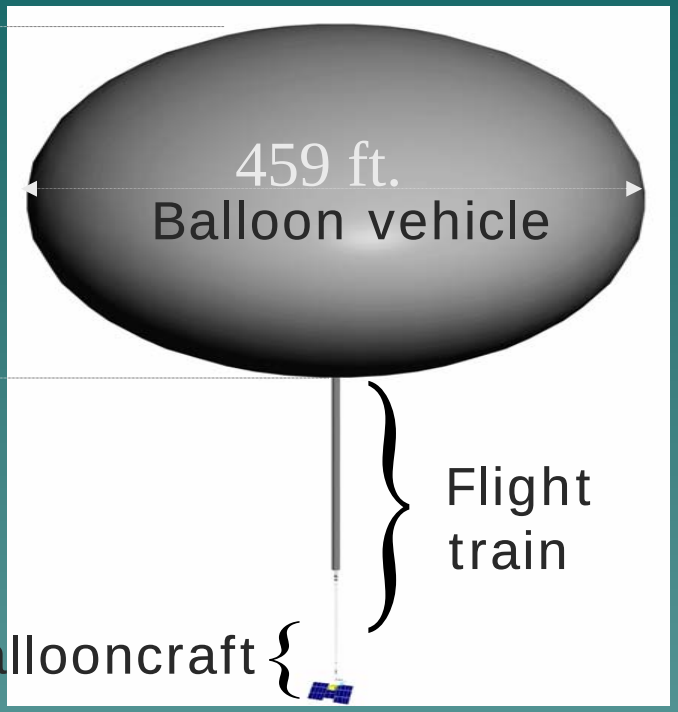
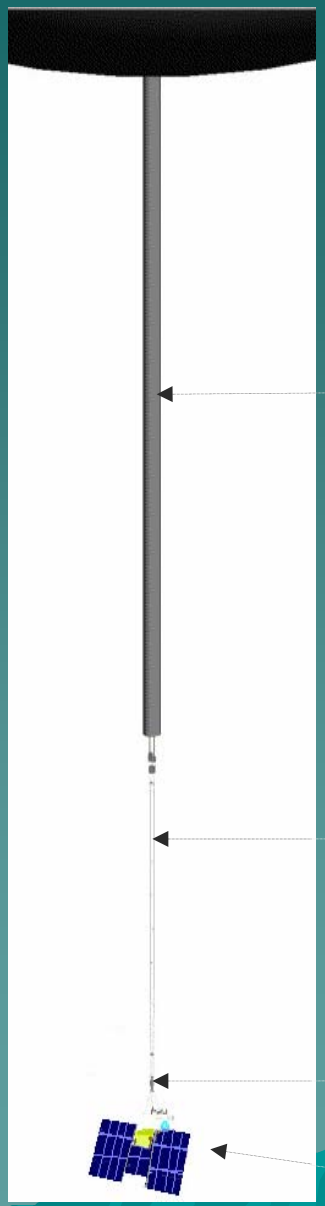
Motivation

- Scientific Balloon ISS Analysis & Design
  - Simple structure
  - Becoming complex
    - Lightweight
    - Longer flight duration
    - Optimization – maintain integrity of science
  - Example using ’04 CREAM campaign
- WFF Mechanical Systems Branch (Code 548)
  - Broad support services in the areas of:
    - Structural analysis
    - Mechanical design
    - Thermal engineering
    - Materials research and development
    - Assembly, integration and testing
  - Balloons Program Office (http://www.wff.nasa.gov/~code820/)
  - http://www.wff.nasa.gov/about/capabilities.php

Scientific Balloons





- Volume: 39.57mcf
- Weight: 4,055lb
- Float Altitude: 125Kft
- Payload: 4,153lb
- Film: 20.32μm (0.8mil)

The Instrument Support Structure

- ISS
  - Assembled set of mechanical components that provide the primary load path to support the weight and inertial loads of the
    - science payload
    - balloncraft support systems
- The National Scientific Balloon Facility (NSBF), Palestine, TX
  - Specifies loading conditions
  - Responsible for flight worthiness certification of the balloncraft
  - Responsible for flight operations

CREAM ISS Initial Design

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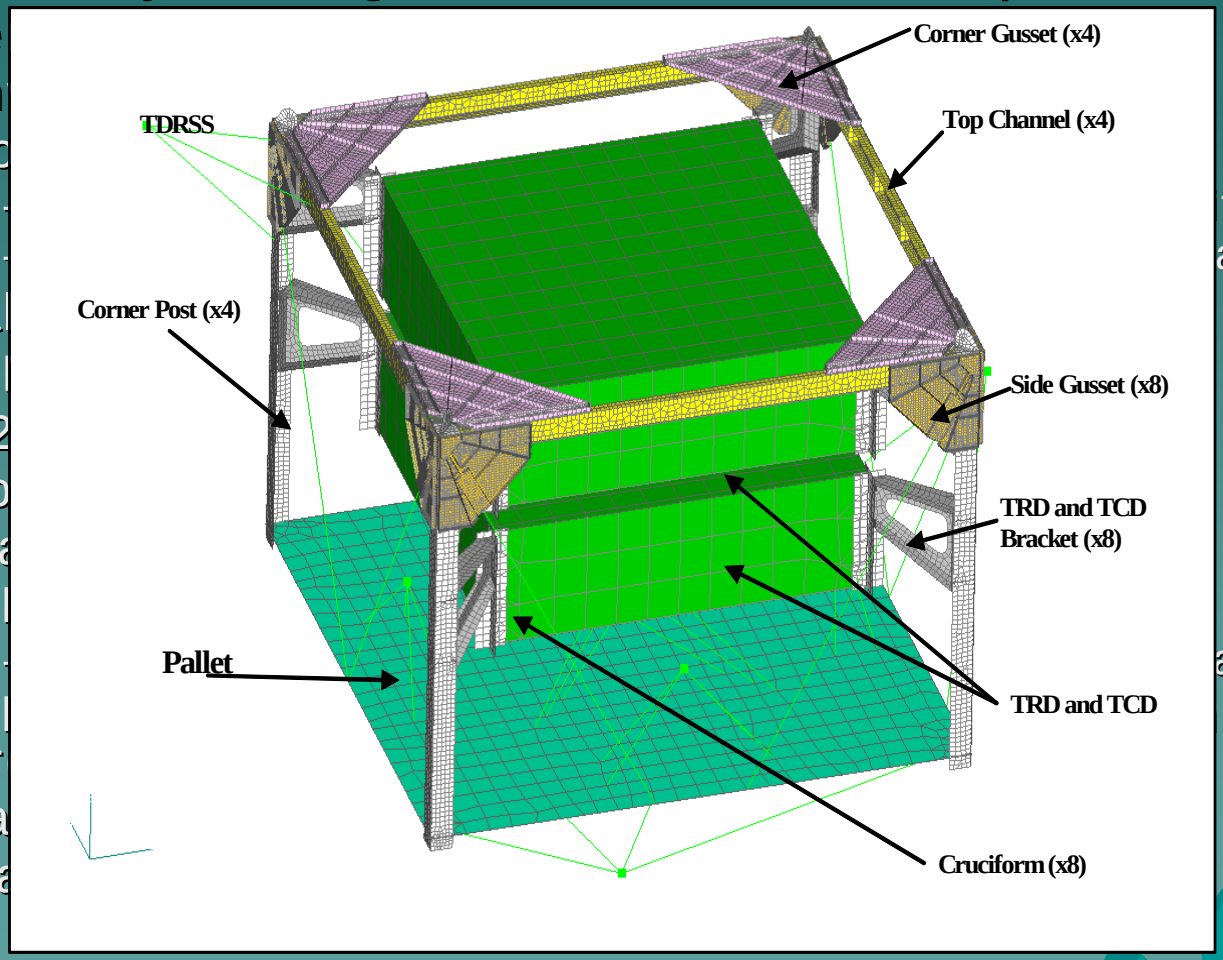
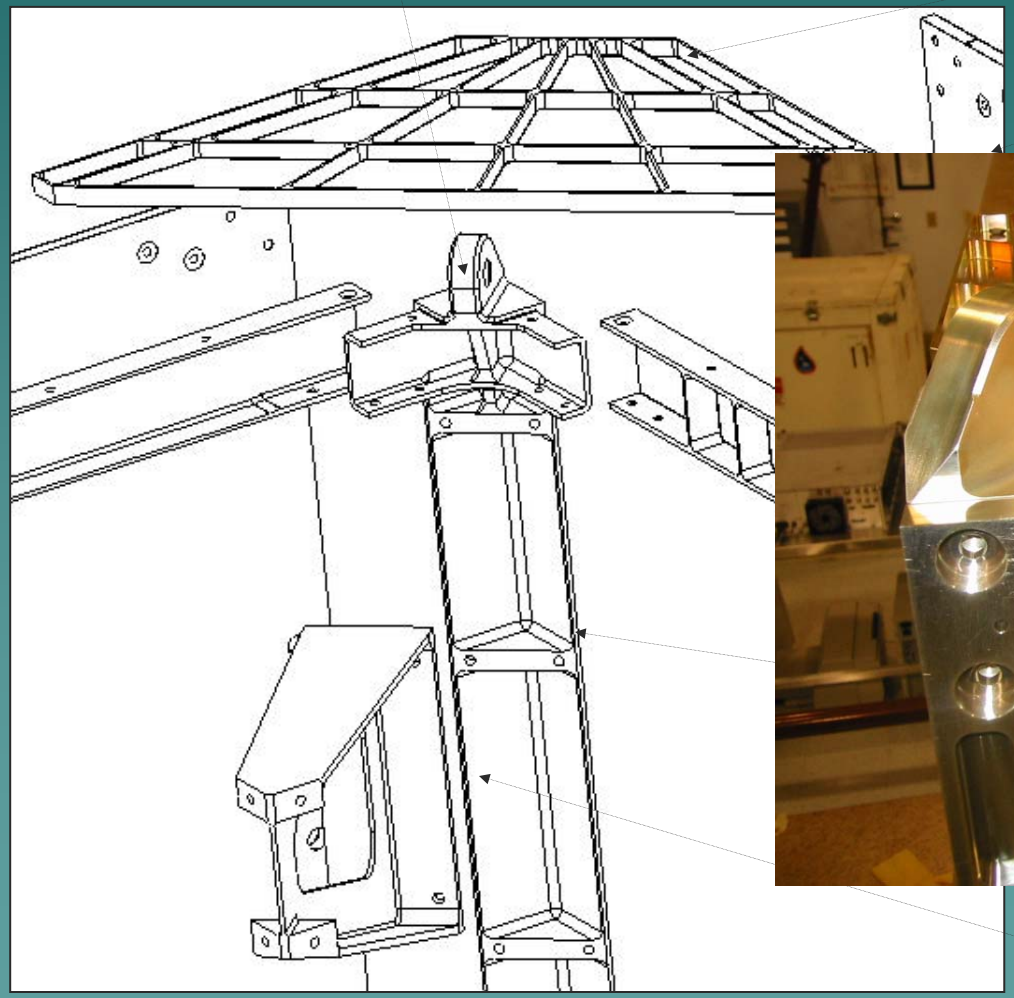


CREAM ISS Initial Design

Cable clevis interface

7075 corner gusset

Radiator panels bolt to top channels and corner post w/ clip



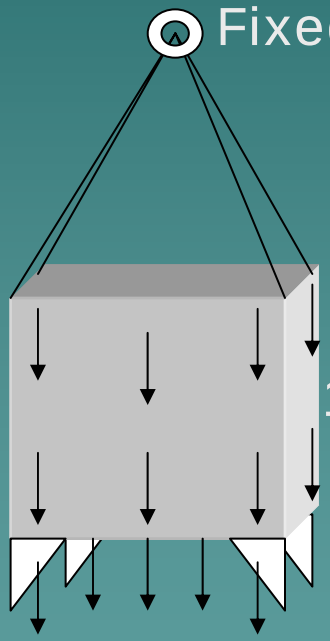
(8) TRD brackets weight optimized

CREAM ISS Initial Design

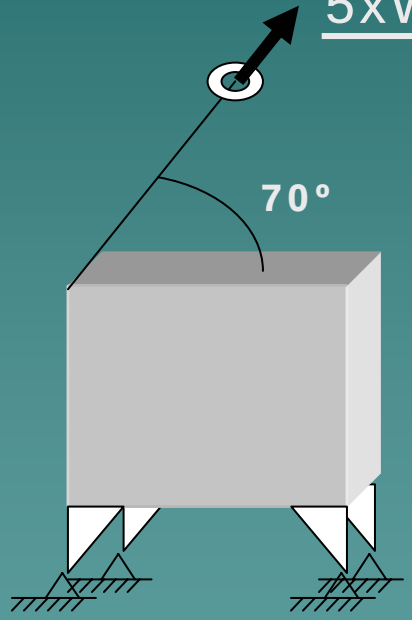
- Loading Condition
  - Transient
  - Applied analytically as a static load
  - Imparted to structure at termination
    - End of scientific experiments
    - Balloon craft & flight train separate from balloon vehicle
    - Balloon free-falls to earth
    - Rest of balloon craft free-falls also
    - Shock load at parachute deployment

ISS – Loading Condition

- The ISS design is such that all load-carrying structural members are capable of withstanding the NSBF prescribed conditions without ultimate structural failure.

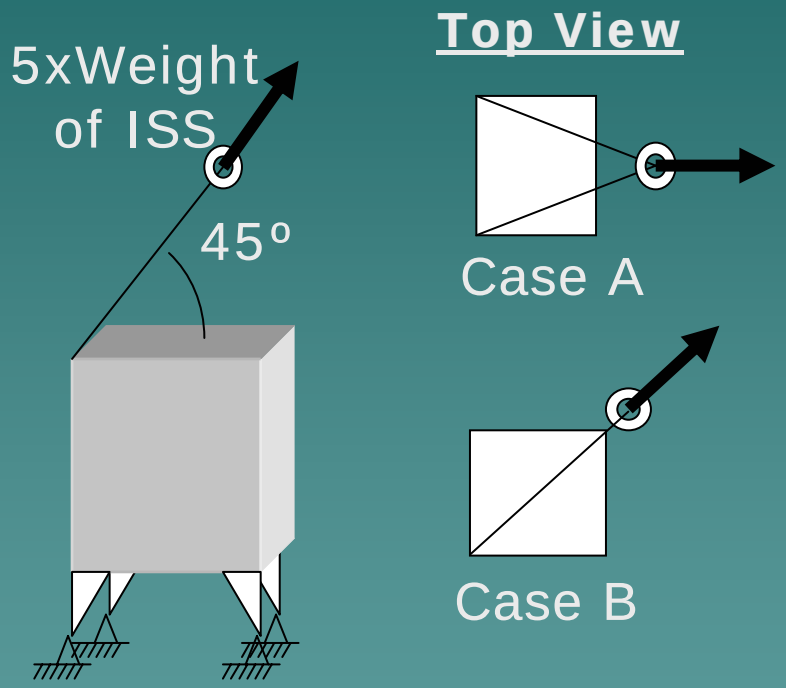


Assumes the ISS falls straight down and is caught by the parachute.

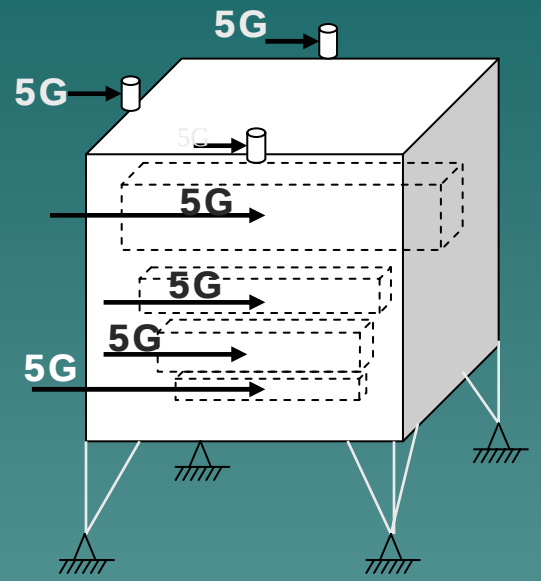


5x safety factor standard for overhead lifting with cables. The load path through the ISS should be as strong as the cable.

Initial Design – Loading Condition



Assumes that the ISS rotates 45° as it falls and is caught by only one or two cables.



Assumes that all components attached to the ISS will remain attached in the event that the ISS rotates as it is caught by the parachute and inertial side loads are applied to components attached to the ISS

CREAM ISS Evolution

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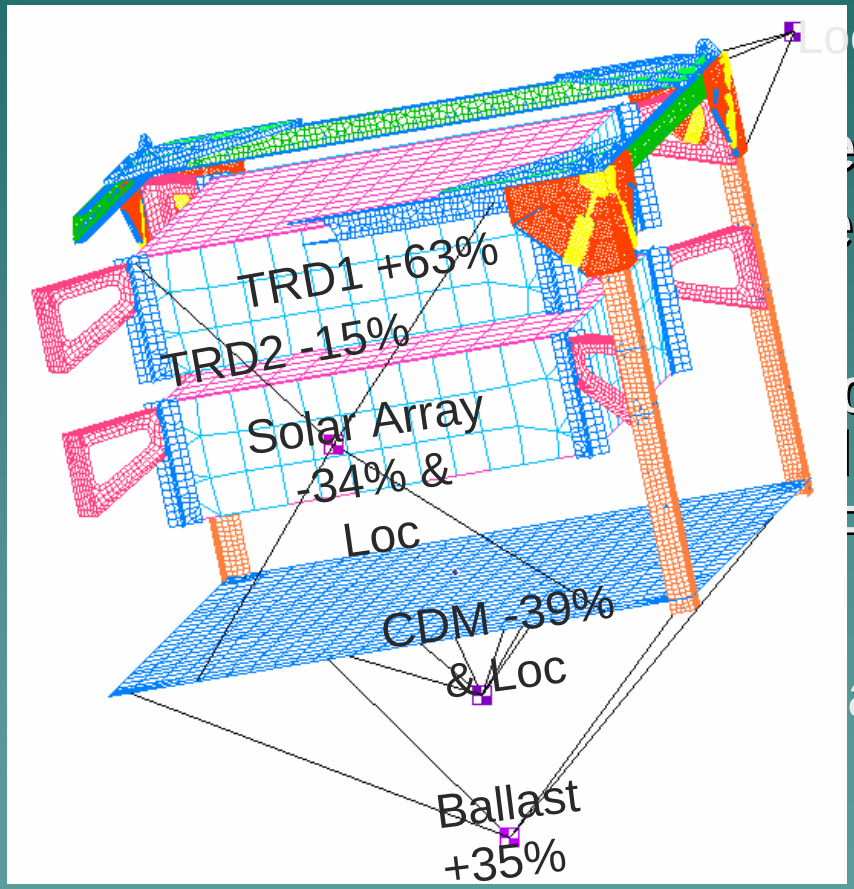
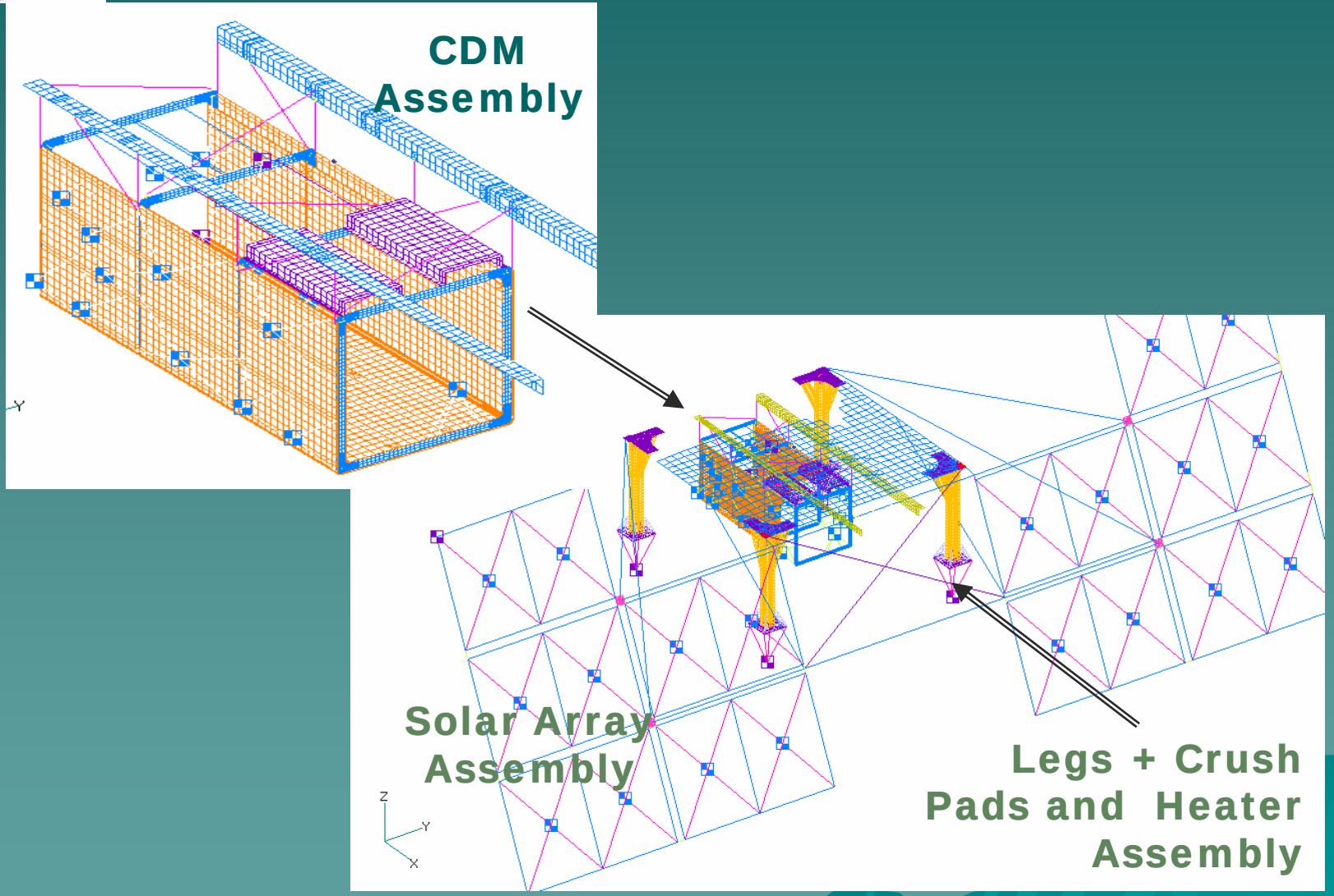
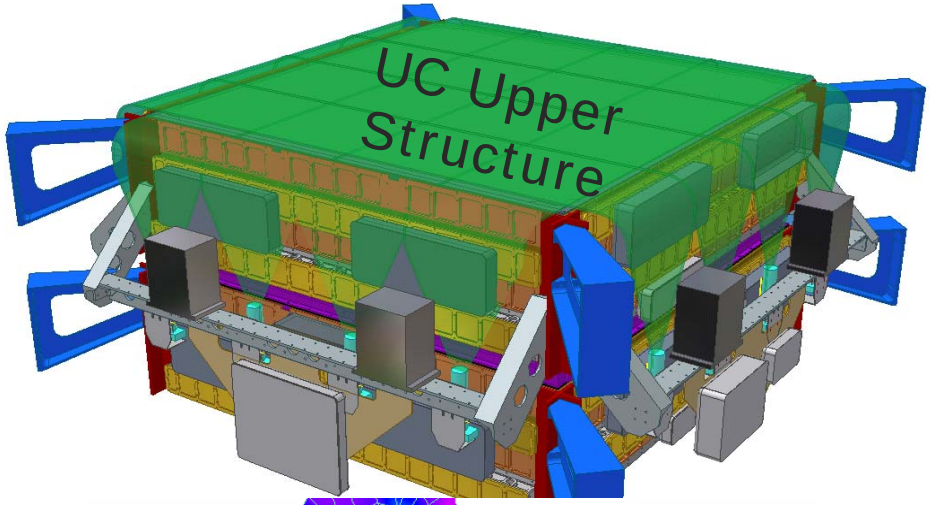


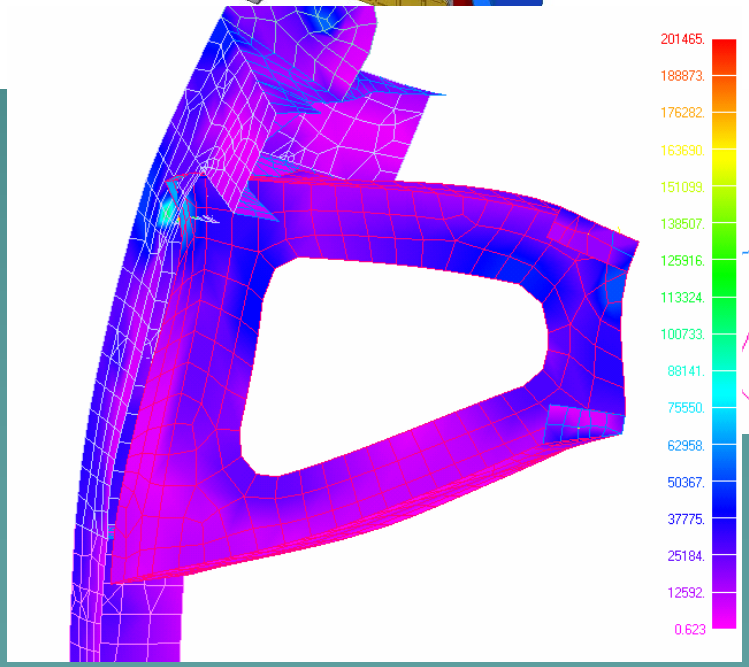
EnglishUnits (in/lb/s)	2003 ISS	2004 ISS
Mass	13.524	13.387
X_{cg}	2.592	-1.387
Y_{cg}	0.208	0.375
Z_{cg}	0.636	-8.909
I_{XX}	8,292.05	23,041.16
I_{YY}	10,120.71	22,310.28
I_{ZZ}	6,067.43	10,190.67
I_{XY}	-138.63	-241.33
I_{YZ}	133.84	263.22
I_{zx}	651.04	-137.59

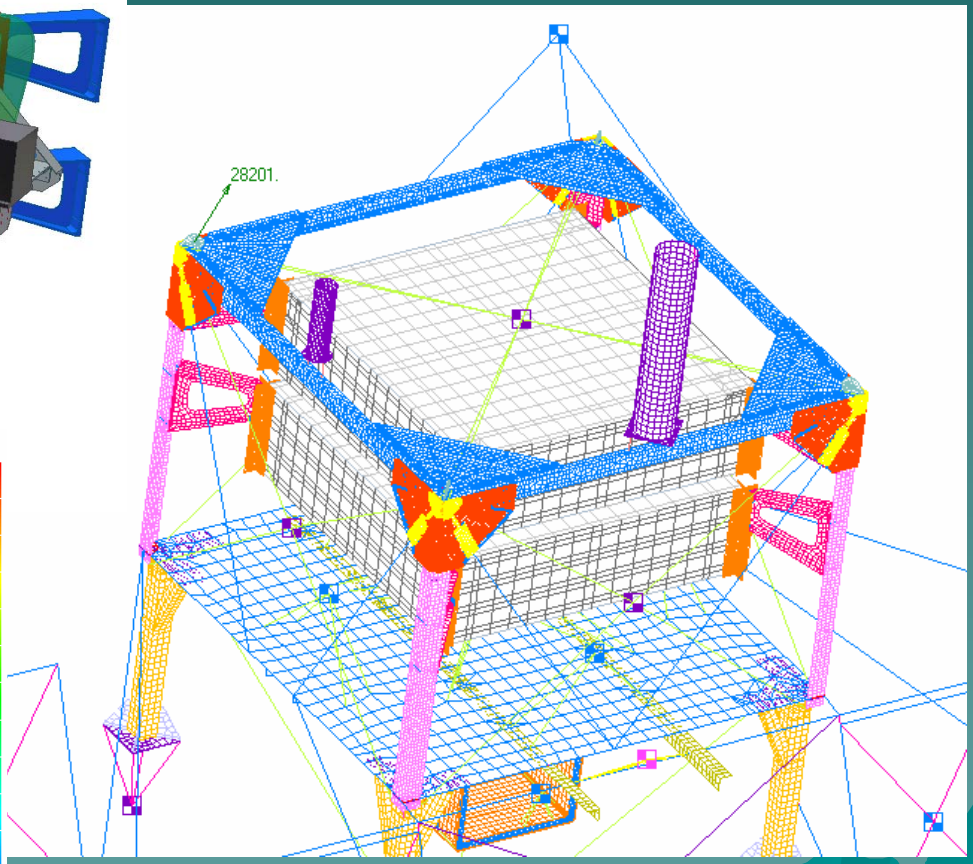
CREAM ISS Design Update



CREAM ISS Design Update

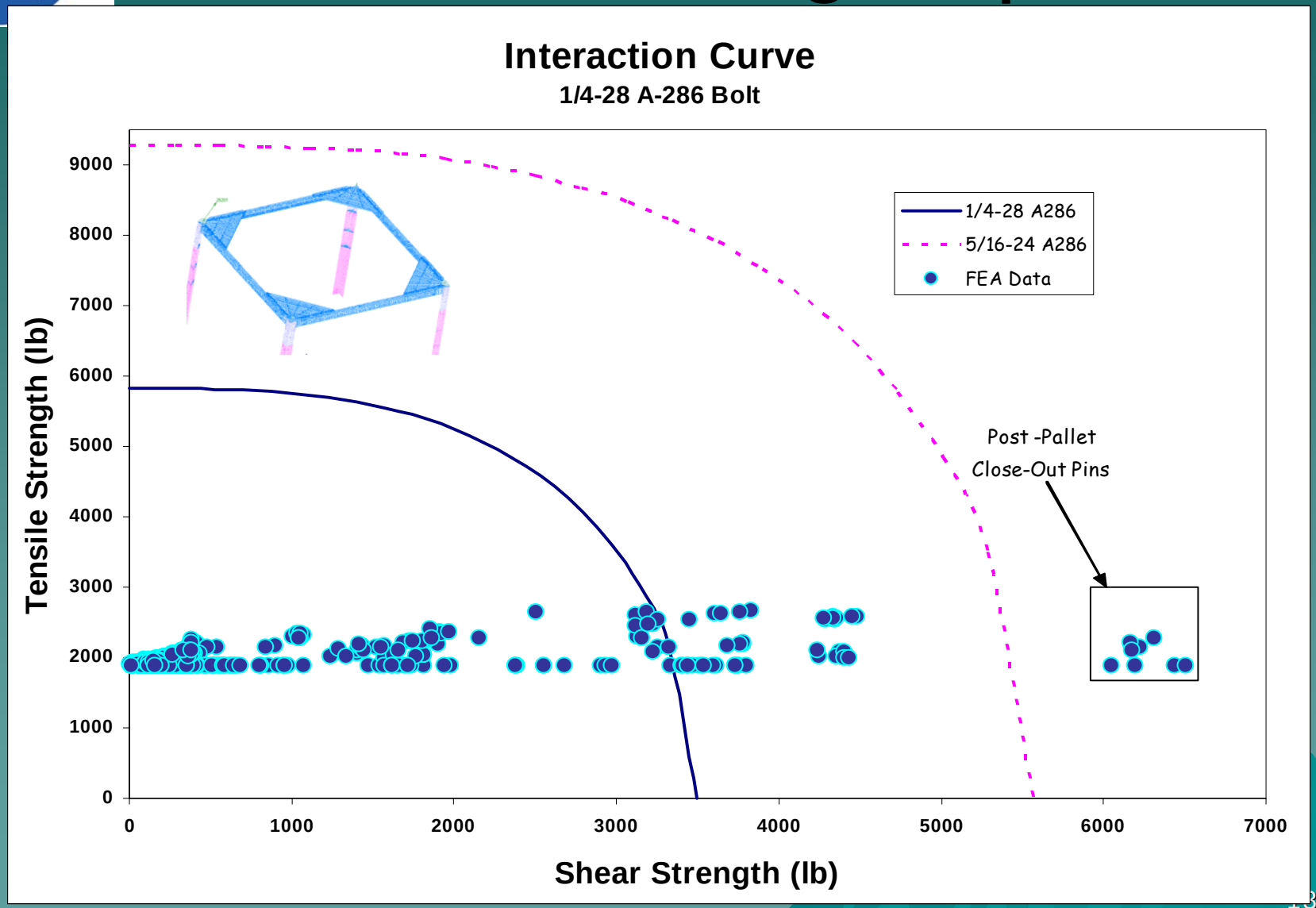




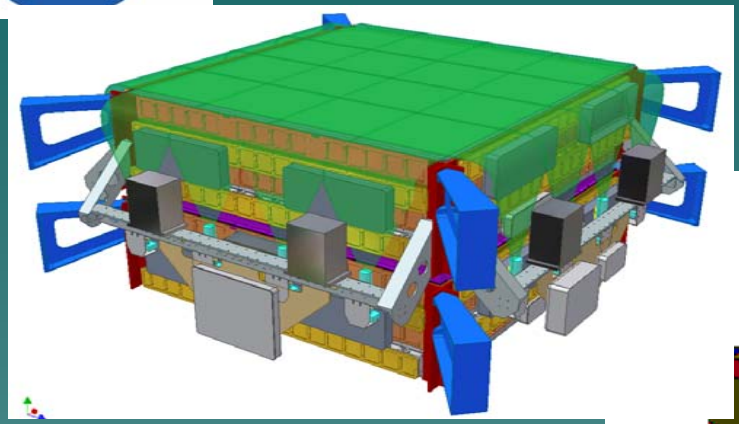


- Problem #1 - Big
  - Massive fastener failure

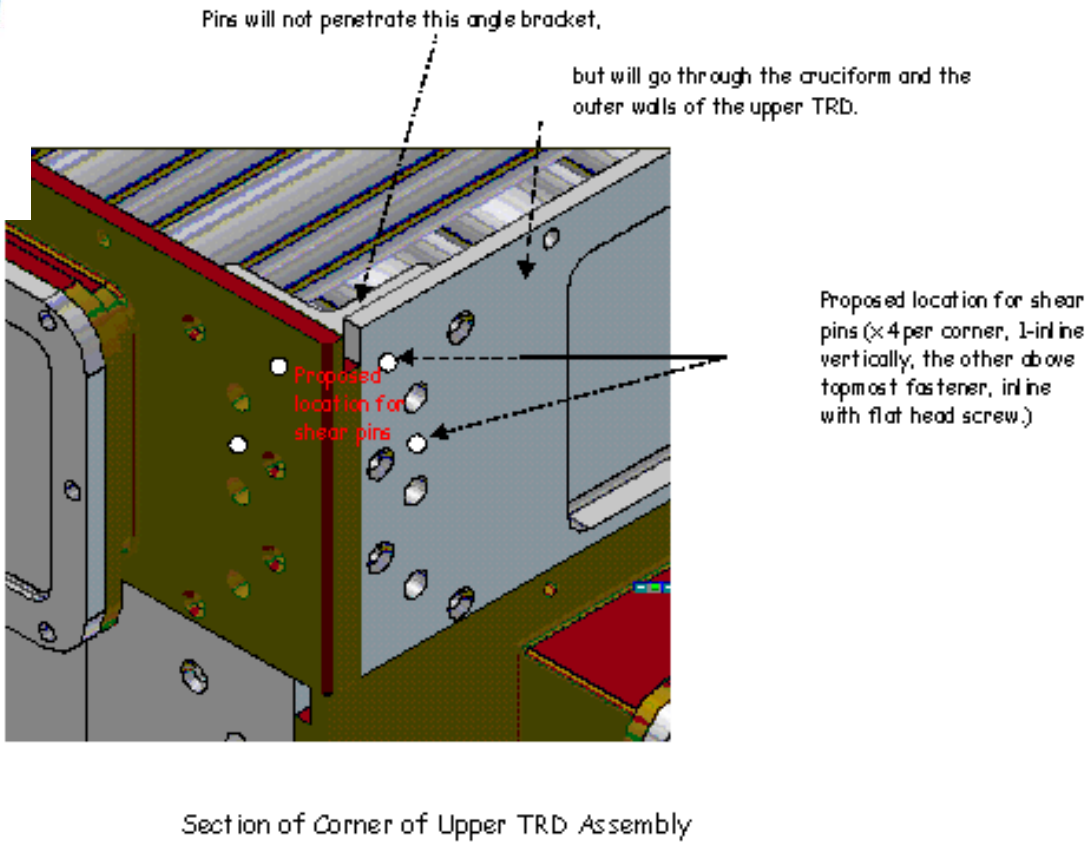
CREAM ISS Design Update



CREAM ISS Design Update



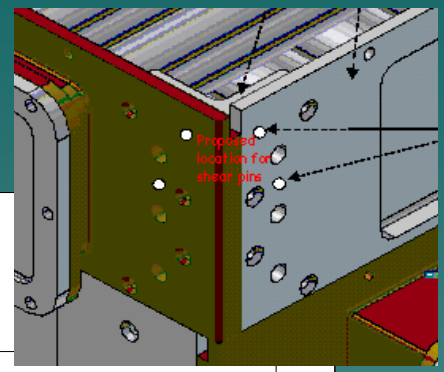
- Fasteners inaccessible for replacement

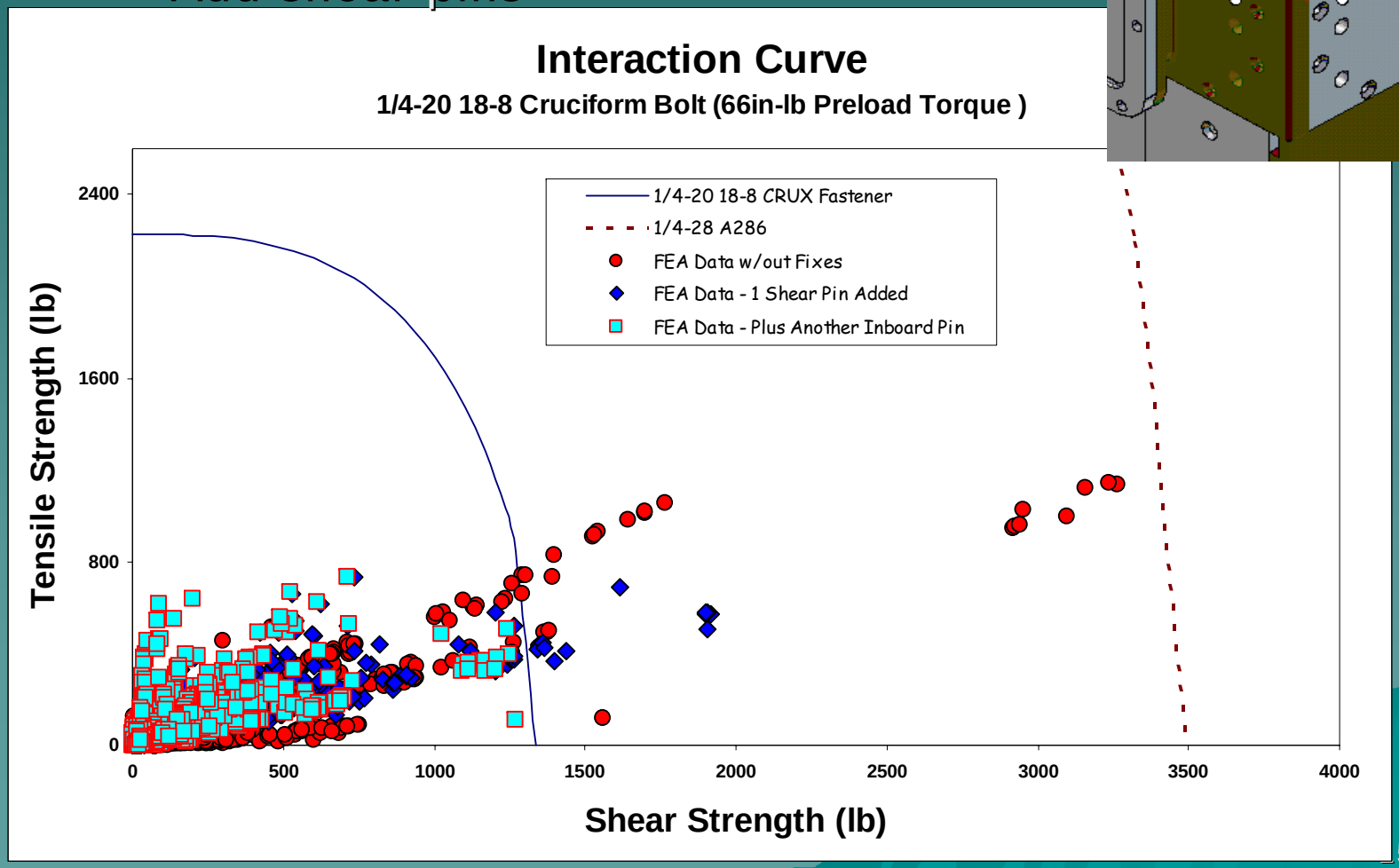


Section of Corner of Upper TRD Assembly

CREAM ISS Design Update

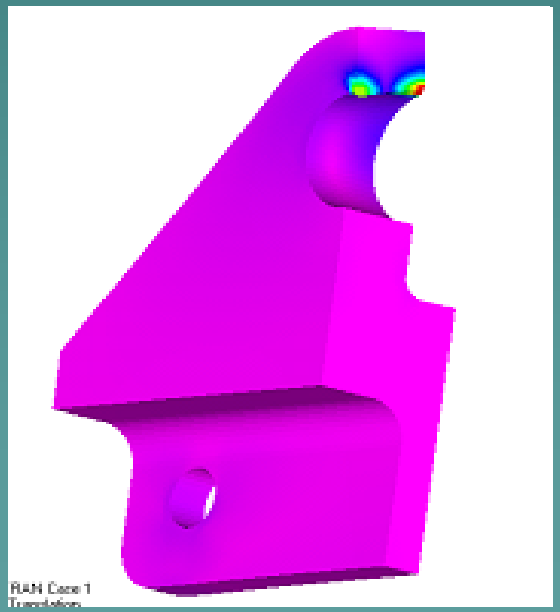
- Solution
  - Add shear pins



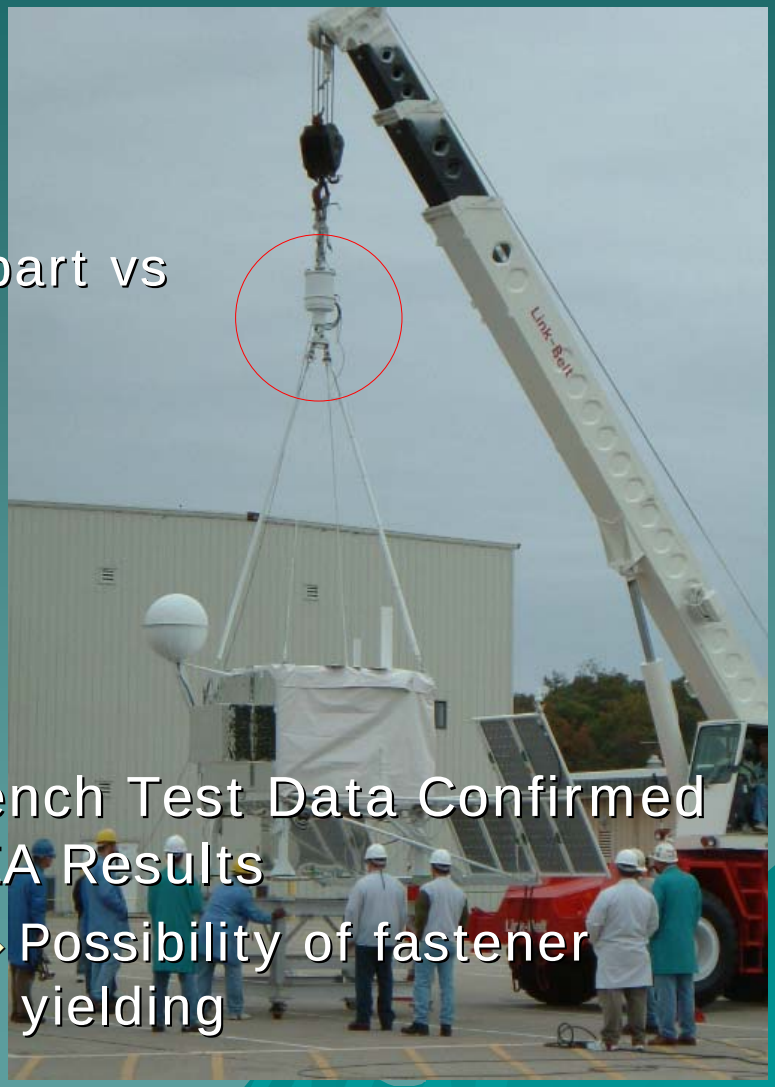


CREAM ISS Design Update

- Problem #2 - Bigger
  - Single point failure
  - Flight tested
  - Conflict: Flight experience with part vs FEA data



Lower Tri-Plate

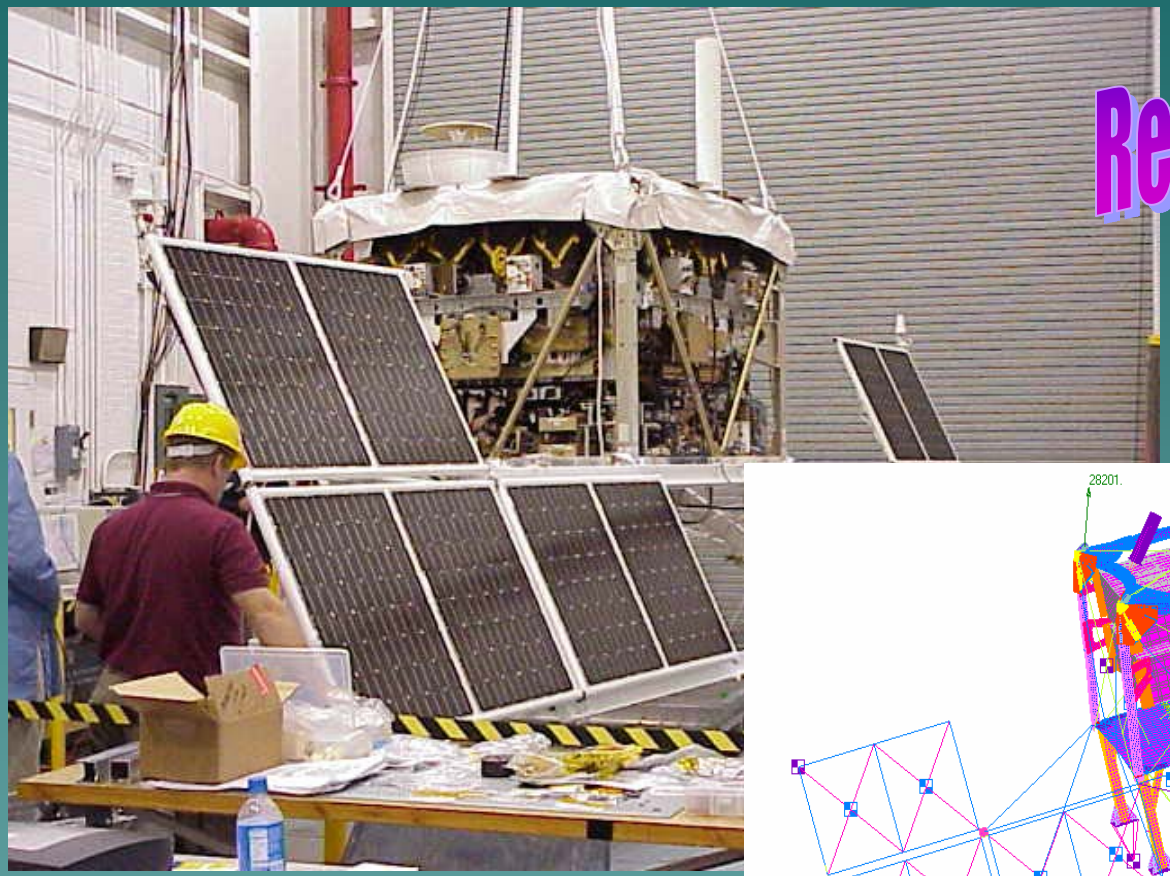


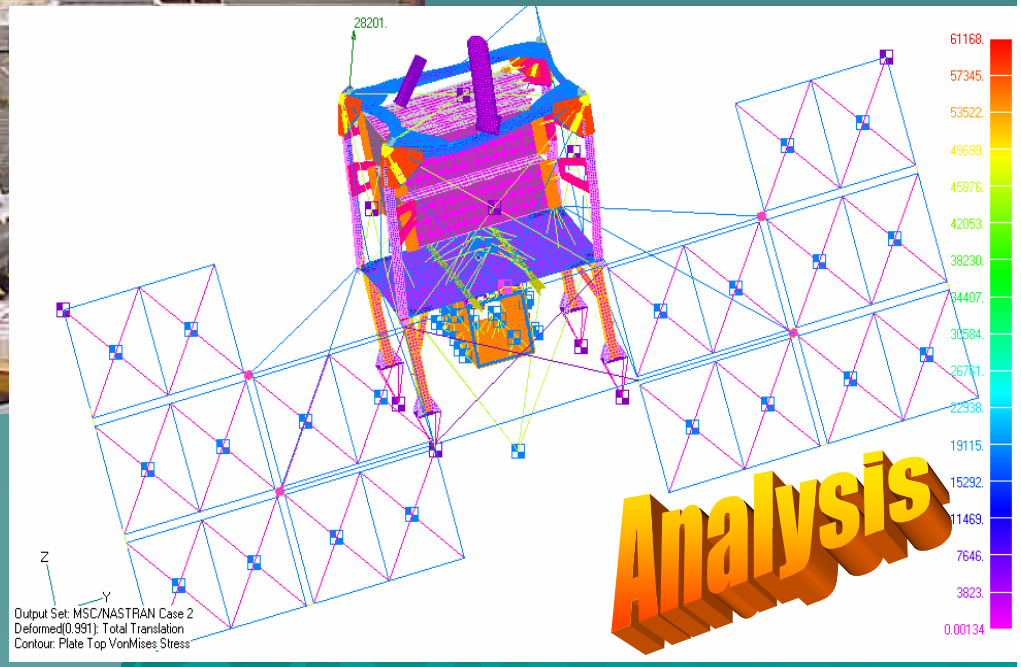
  - Bench Test Data Confirmed FEA Results
    - Possibility of fastener yielding

ISS Design & Analysis Challenges

- What failure criteria to apply?
  - Yield/ultimate
- Quick turn-around flight
  - Re-flight → aborted primary flight
  - Re-flight → opportunity
  - Post yield & post buckling analyses
- System Constraints
  - ULDB vs LDB missions
  - ISS boundary conditions
- Loading Condition
  - Better definition of termination loads

CREAM ISS - Images

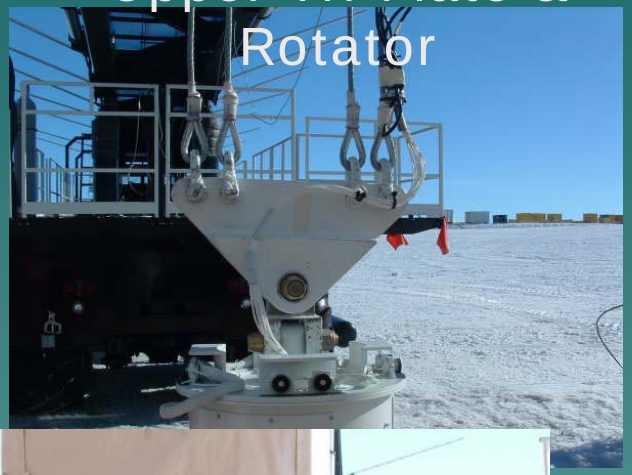




CREAM ISS - Images

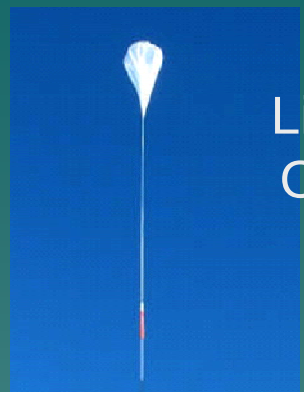
Lifting Exercises

Upper Tri-Plate & Rotator



Men @ Work

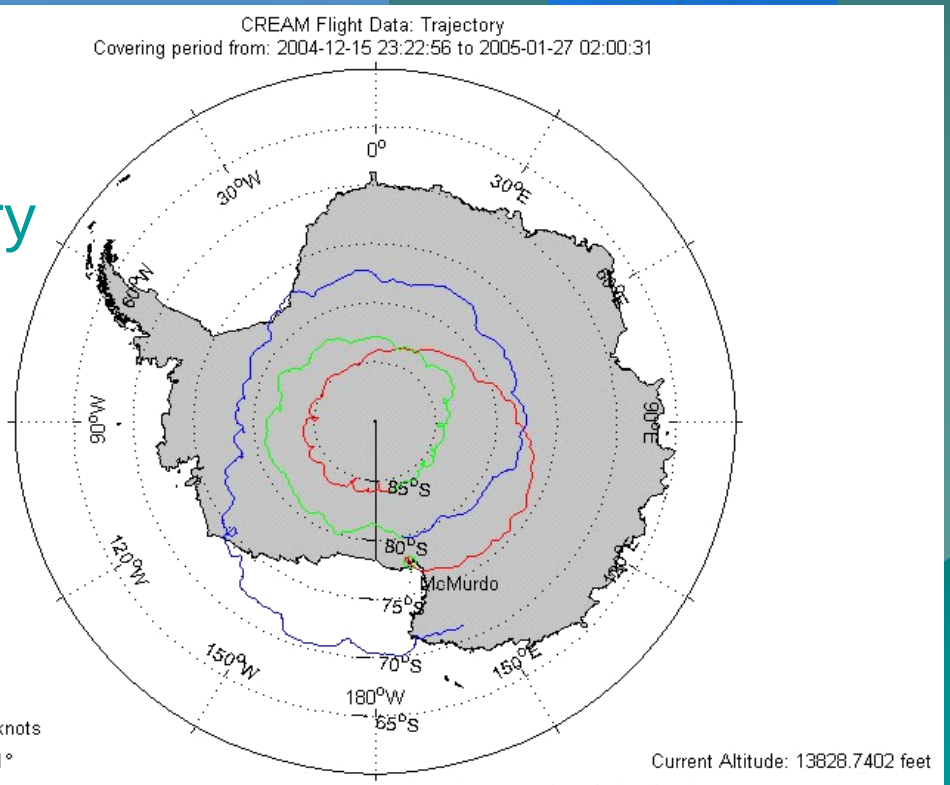
CREAM ISS - Images



Lift-Off

Balloon Inflation

Balloon Trajectory



Current Speed: 17.2 knots
Current Course: 128.1°
Current Lat: -71°17′3.72″
Current Lon: 157°52′54″

Current Altitude: 13828.7402 feet
Current MET: 41 days 21 hrs 31 mins 30.783 sec since launch
Current Time: 2005-01-27 02:00:31 UTC

CREAM ISS - Images

Landing & Recovery