SPACE STATION
SOLAR ARRAY JOINT REPAIR

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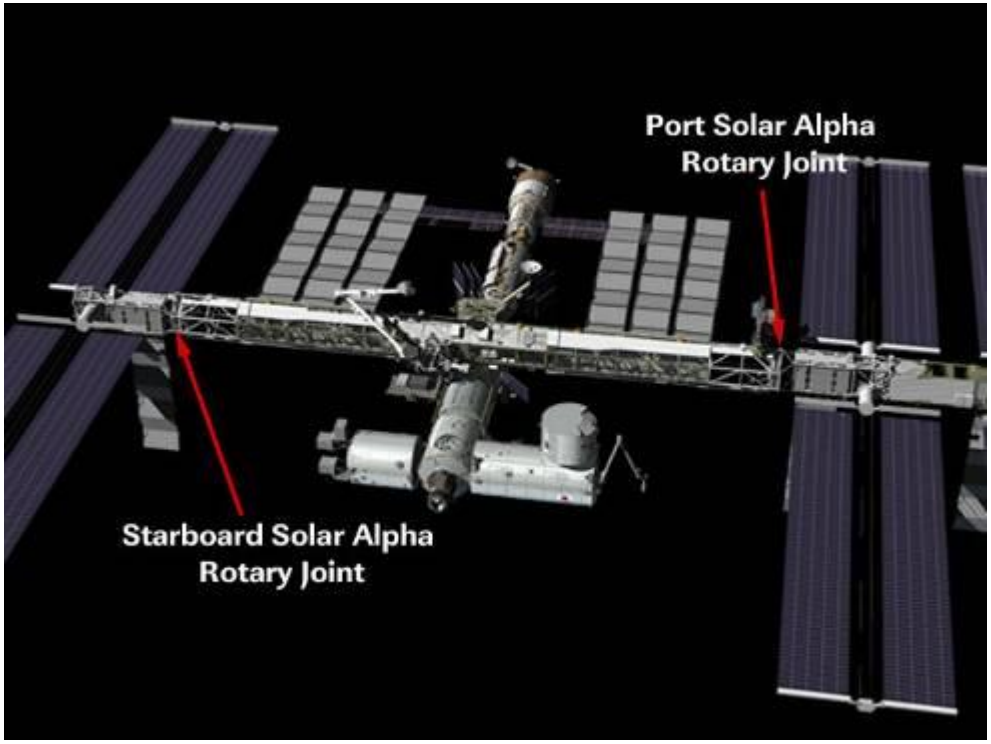
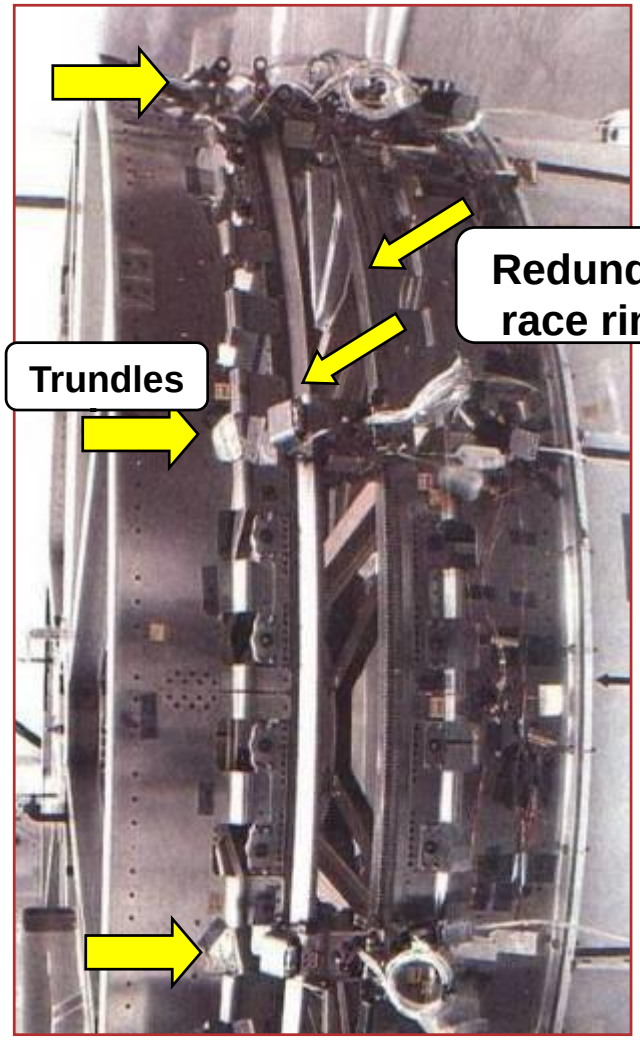
Solar Alpha Rotary Joint (SARJ)

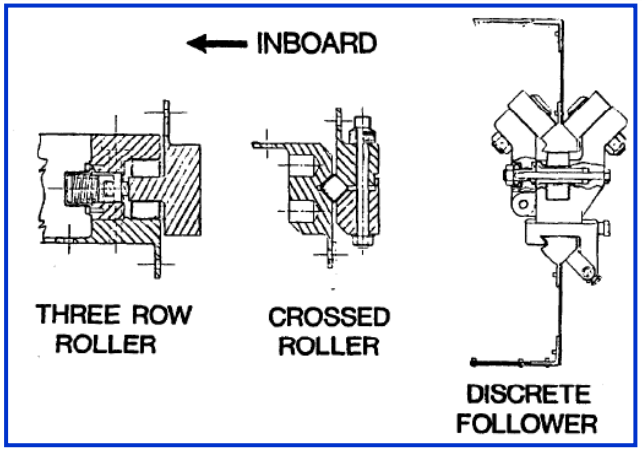




- **SARJ orients port & starboard solar array wings to sun providing power to station**
  - **12 Trundle Bearing Assemblies support a 10.5 ft diameter race rings (redundant)**

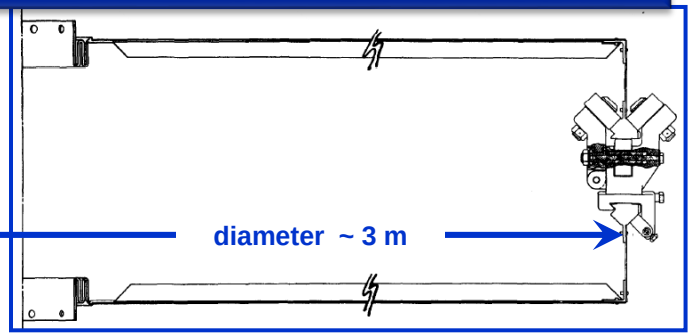
SARJ Trundle Bearing Assys & Race Ring

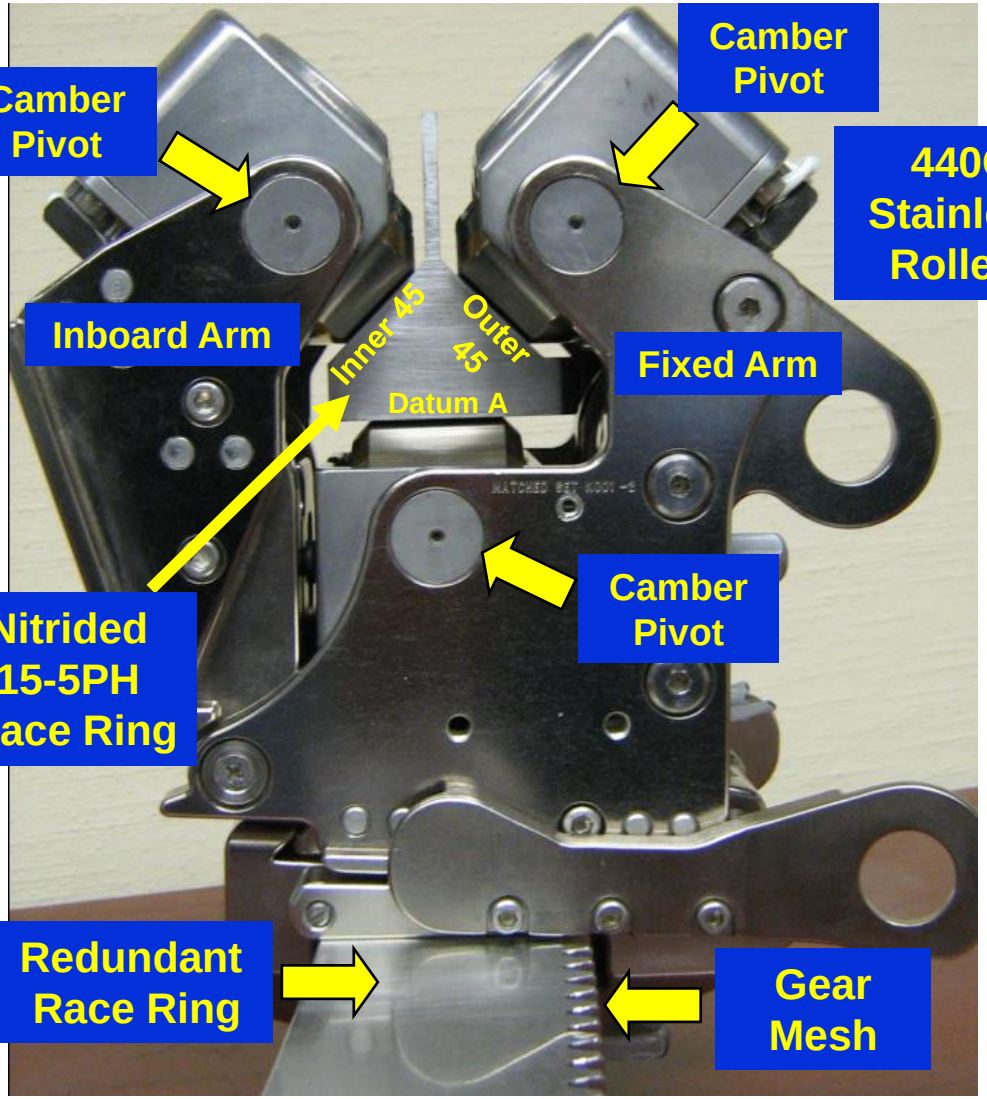
Candidate Bearing Configurations



Trundle Bearings

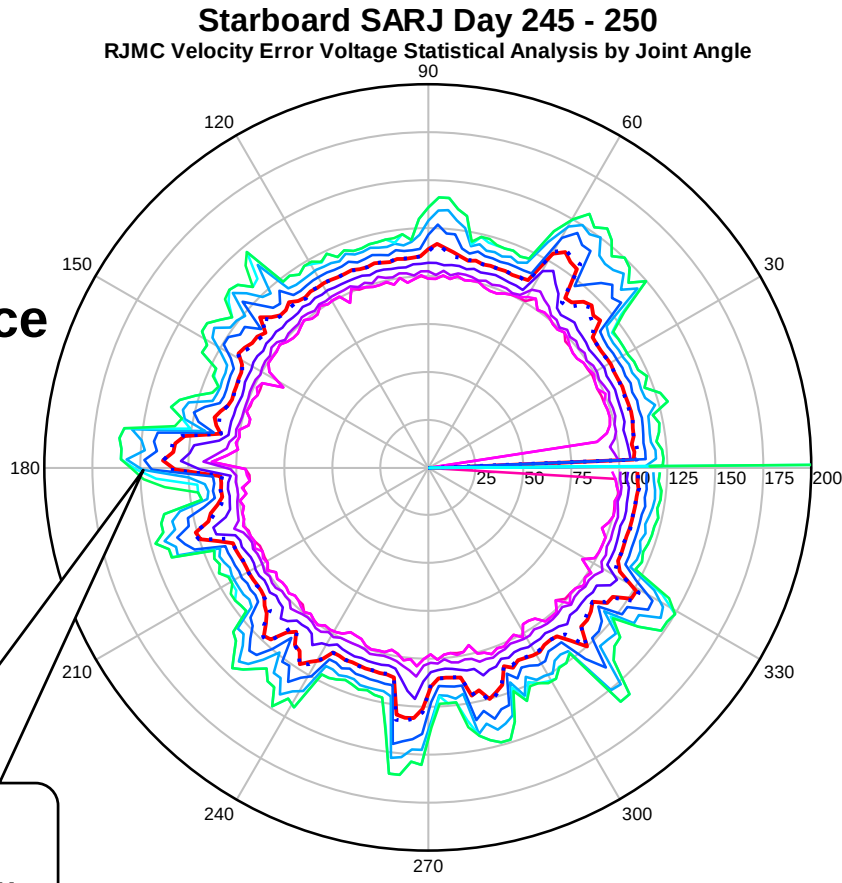
- Less Sensitive to Temp
- Easier to Replace
- Lighter
- Easier to Make





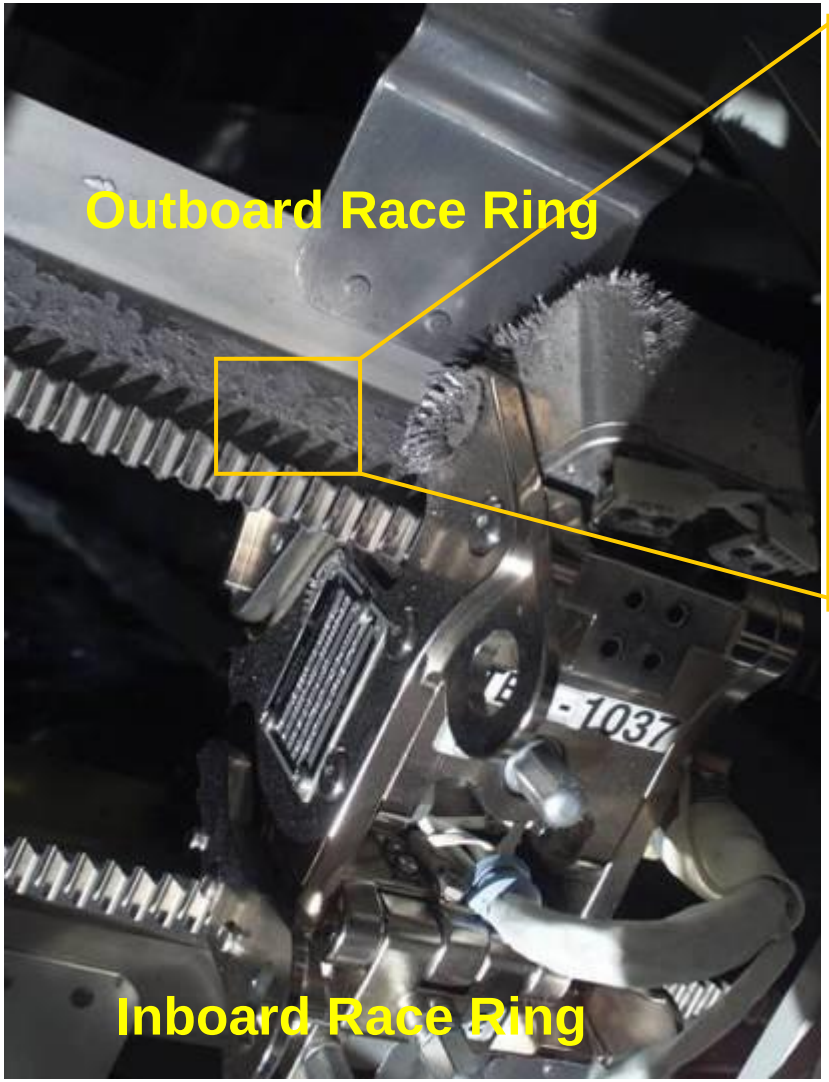
The Problem

- **On 22 Oct 2007, ISS crew noticed vibration on camera in vicinity of Starboard SARJ**
  - **Unit had less than 4 months running time**
- **Velocity trace showed irregular servo errors at several clock positions**
- **Crew sent out to inspect and found race damage on outer 45 deg track**
- **Inner 45 deg & Datum-A races Okay**
- **Port SARJ races Okay ≈14 months at time of inspection**



Starboard SARJ velocity error changing each day

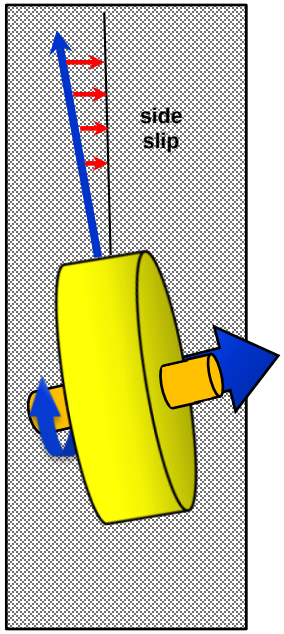
Outer 45 Deg Race Shows Significant Damage



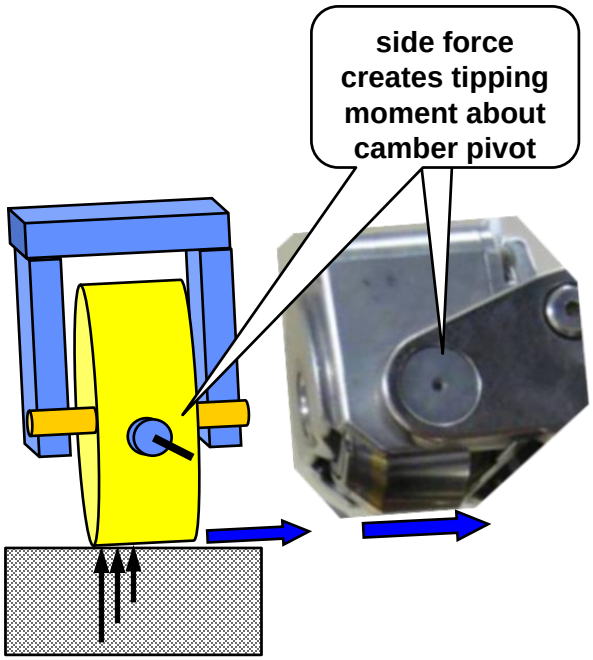
- Outer 45 deg race damaged
- Nitrided case spall fragments and ground up fine particles collected

fatigue striations

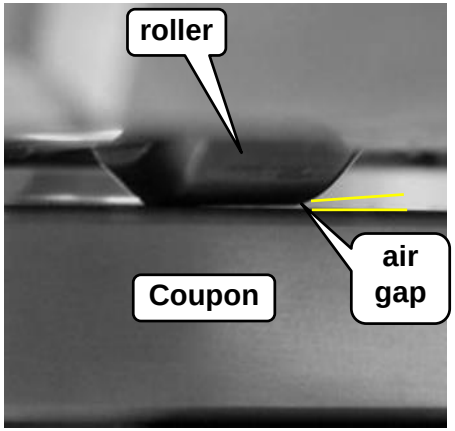
Tipping Mechanism



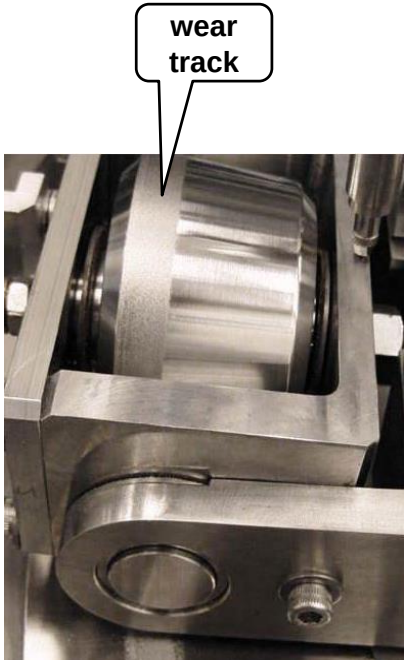
misaligned roller creates side slip between roller & race



tipped roller creates high edge contact stress



tipping confirmed

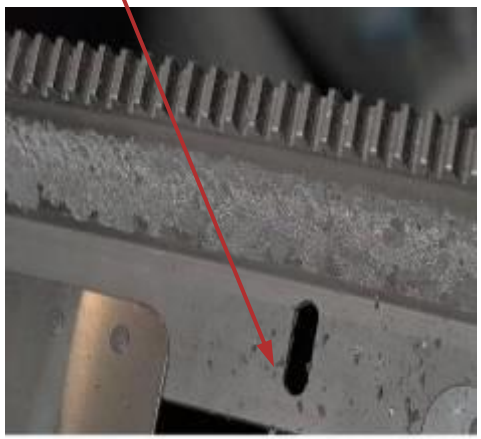


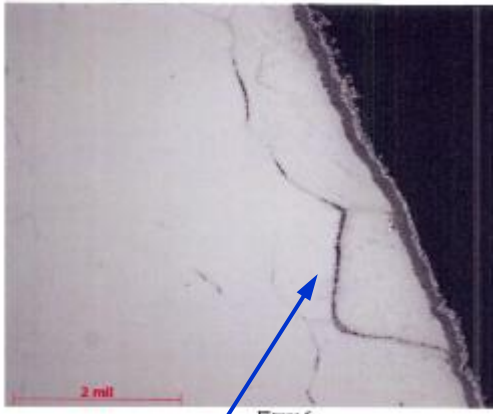
wear on edge of mistracked roller

Side force from misalignment plus high friction creates tipping and high contact edge stress

Failure Investigation

- **Government –Industry team formed to determine root cause**
- **Root cause found to be roller misalignment (aka mistracking) coupled with high contact friction**
  - **generates tipping and high roller edge contact stresses**
  - **edge stresses high enough to crack/fatigue the nitrided case**
  - **intergranular networking (crack-like separations) likely contributed to damage**
- **Least difficult repair would be to lubricate the SARJ tracks with grease**
- **How do we validated this fix and how long will it last between regreasing?**
  - **build a high fidelity SARJ life test rig**



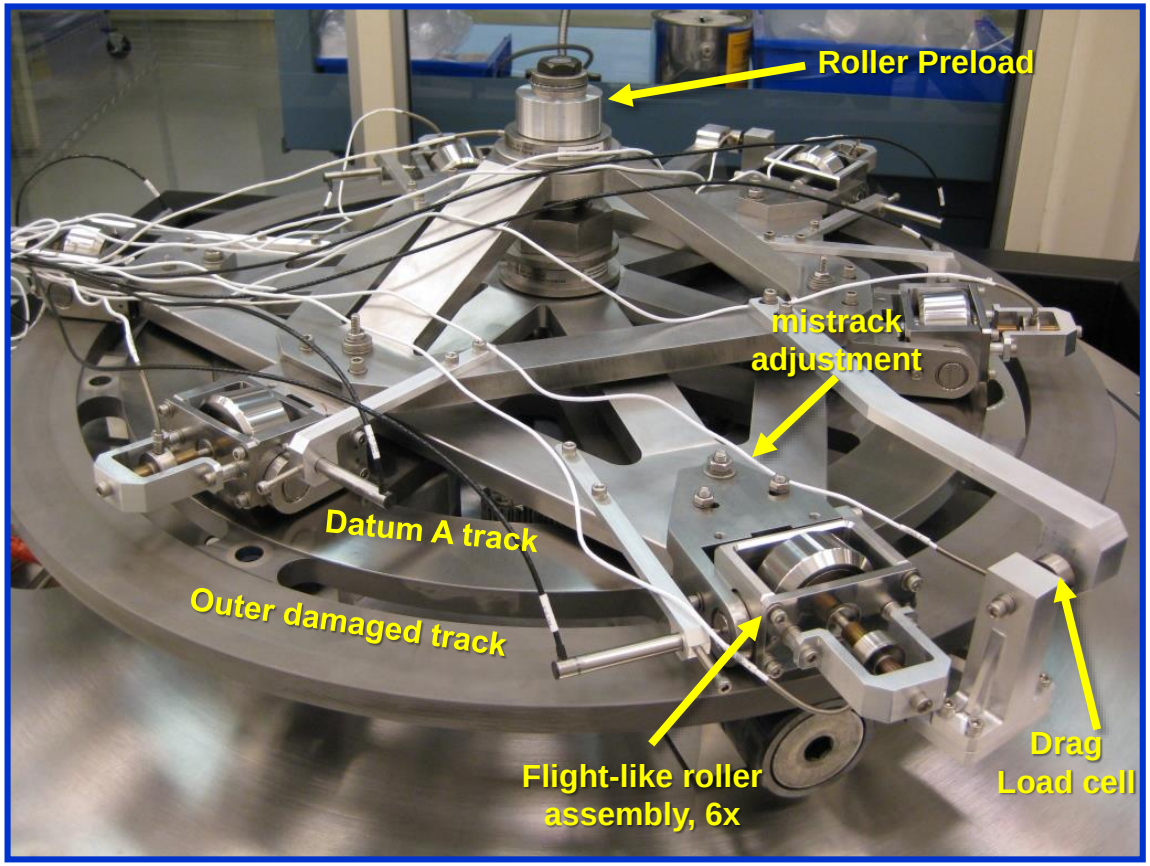


Intergranular networking in nitrided case

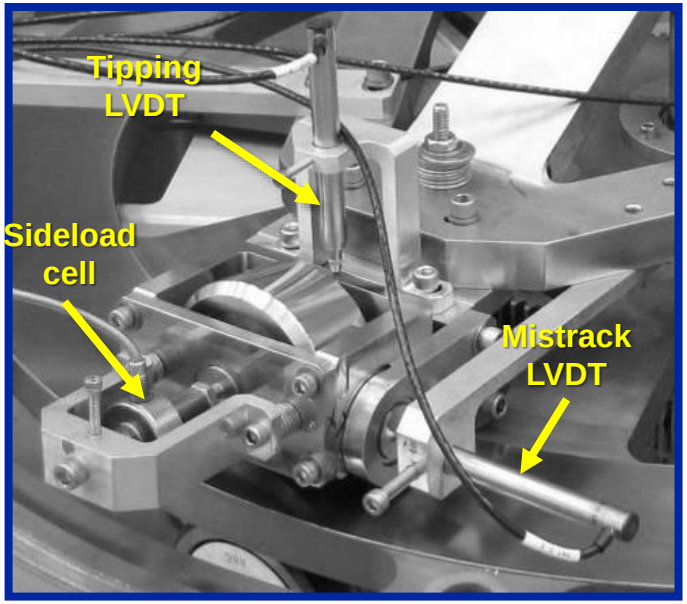
Test Rig Parameters

- Test rings diameters scaled by factor ~ 3 from flight
  - able to fit into a reasonably sized vacuum chamber
- 3 full size, flight-like trundle roller assemblies selected vs normal 12.
- Track diameter sized to keep roller spacing same as flight
- Test plate is flight-like (same materials, heat-treats, surface finish)
- Outer track simulates damaged 45 deg outboard starboard flight race
- Inner track simulates undamaged Datum A roller contact
- Rollers have flight diameters, hardness, surface finish and profiles
- Mistracking angle set to 0.37 deg high-nominal
- Test Rig runs 24/7 with continuous data recording & safety shutdowns
- Side friction, drag & tipping angle recorded
  - as indicator of lubrication degradation
  - provides on-orbit health trending data
  - trigger limits for rig safety shutdown
- Vacuum (<10^{-5} torr) at ambient temp

Proving the Race will Last with Grease

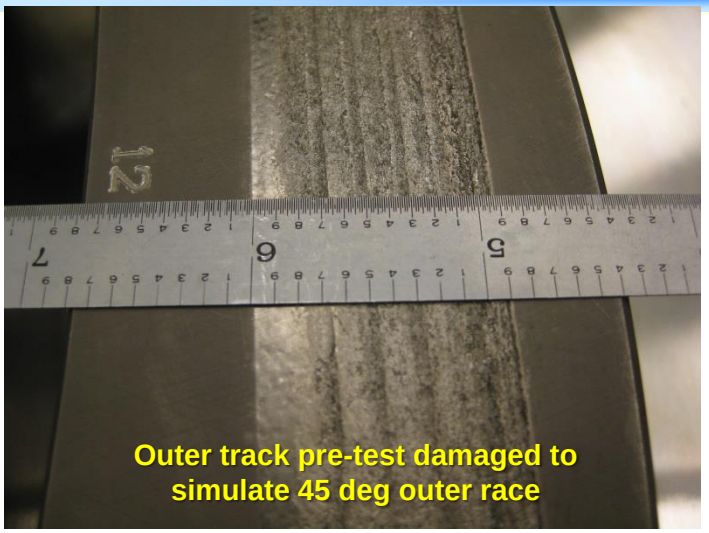


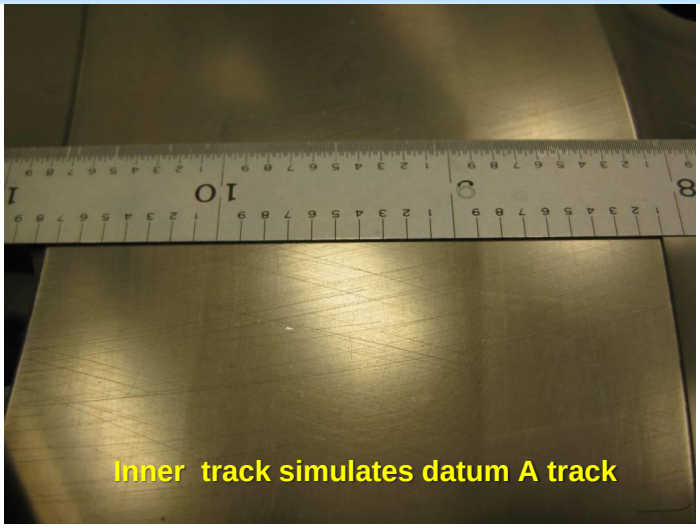
SARJ LITE Test Rig outside of vacuum chamber

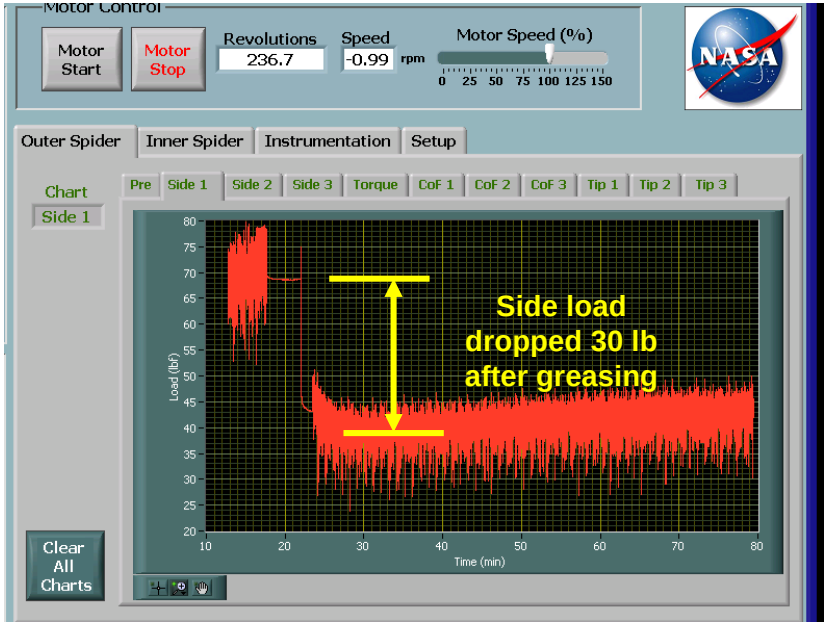


Each Roller Trundle Assembly is Well Instrumented

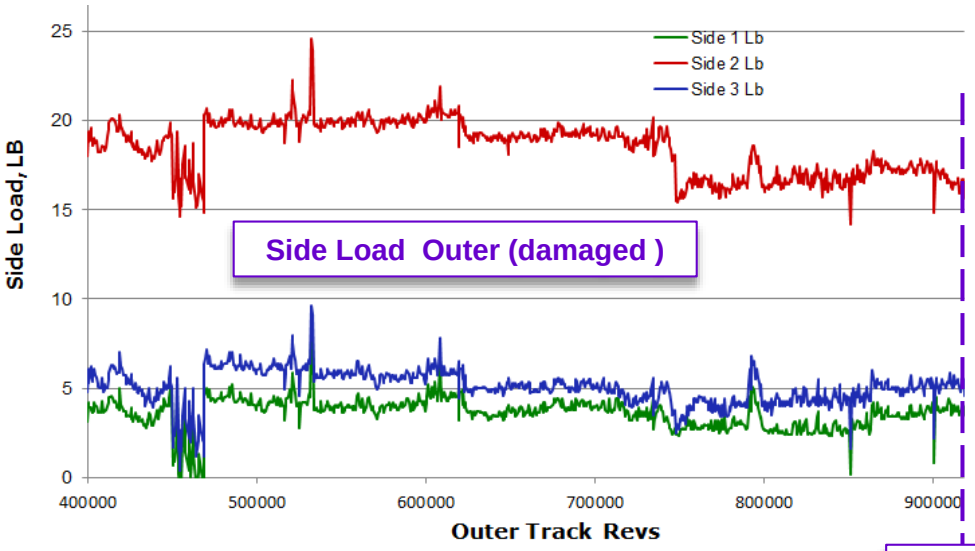
Outer and Inner Tracks Simulate On-Orbit SARJ

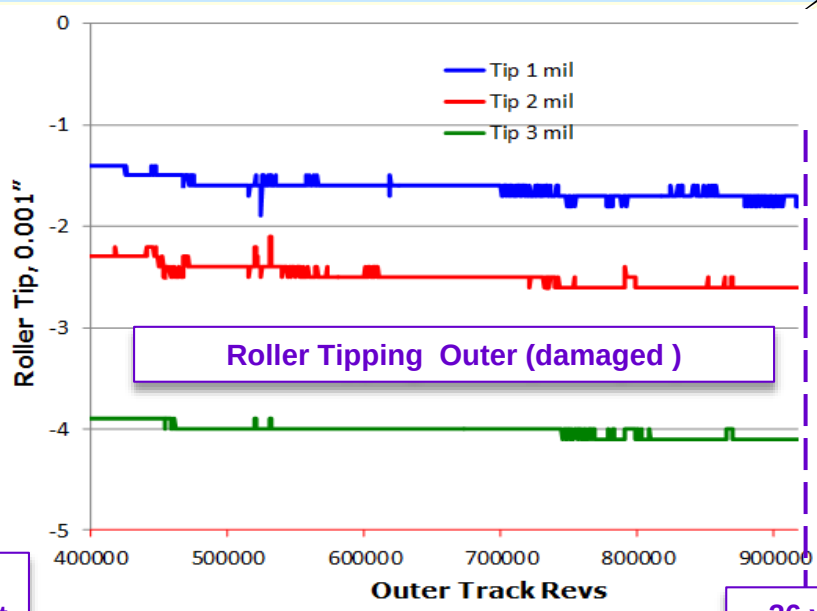




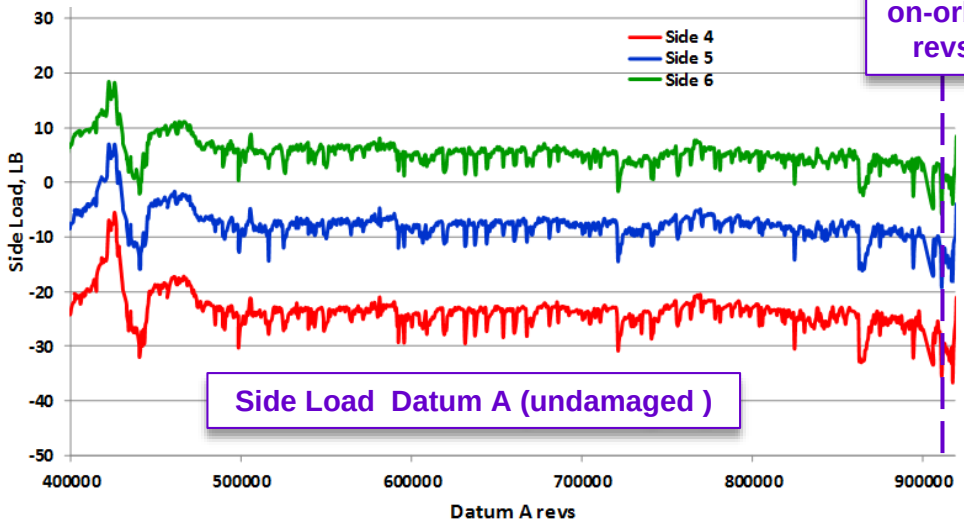


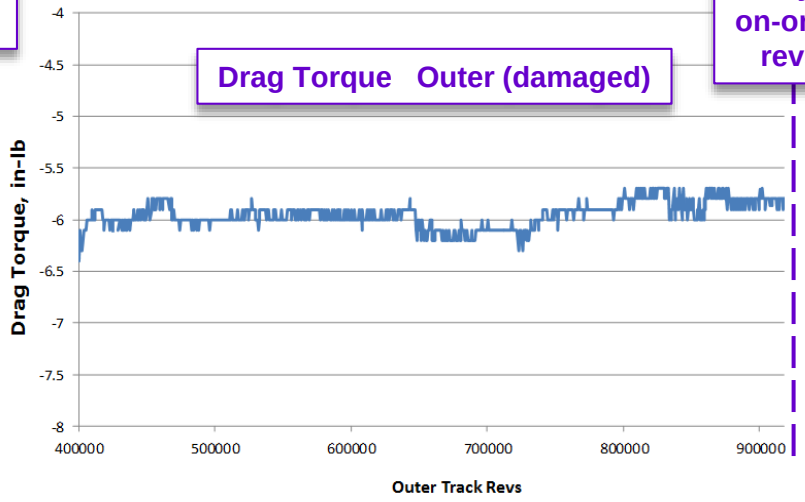
Test Results Showed Relatively Steady Contact Friction Levels, Roller Tipping and Drag Torque Throughout Test





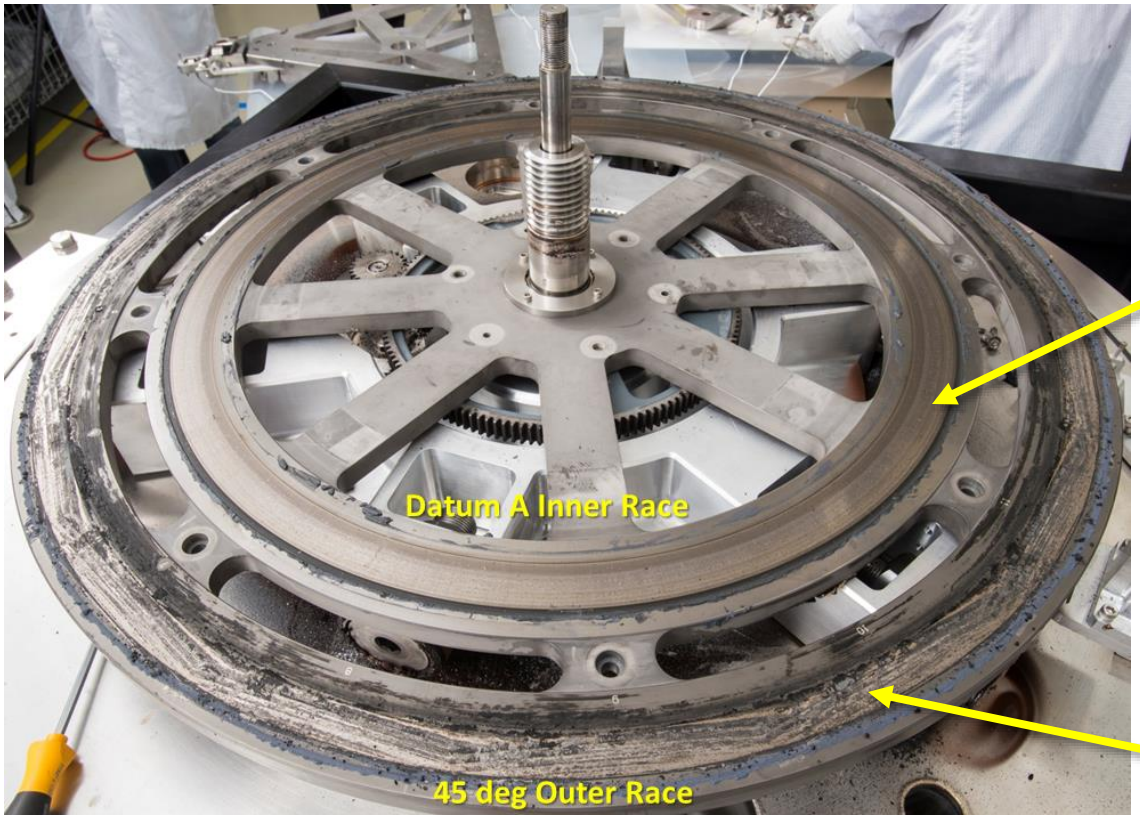
36 yr on-orbit revs





36 yr on-orbit revs

Test Tracks at End of Test



Inner and outer test tracks

Datum A inner track

45 deg outer track

Both Tracks showed Minor Wear after 36+ Equivalent On-orbit Years

Post Script:
SARJ Races Greased (STS-126 Nov 2008)

- Rollers replaced on damaged SARJ
- Starboard & Port Races cleaned & greased.

Motor current and vibe levels returned to near normal

- rose slightly through the years but still well below safe levels