



National Aeronautics and  
Space Administration

**Jet Propulsion Laboratory**  
California Institute of Technology  
Pasadena, California

*JPL is able to apply its technologies,  
facilities, and expertise to assist our  
partners in product improvement and problem  
solving to reduce risk.*

***Flight Materials  
Contamination Overview***



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# Flight Materials & Contamination Engineering Group 3536

## Brief Overview

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## Flight Materials & Contamination Engineering, Group 3536 Brief Overview



- **Materials Databases:**
  - Engineering properties, reference library, Engineering Standards, new technology infusion
- **Programmatic: M&P Control Plans (Project specific)**
  - Materials Identification and Usage Lists, Materials Usage Agreements
  - Cognizant Engineer positions, hardware fabrication, contract management
- **Metallurgy:**
  - Alloys, corrosion, heat treatments, galvanic couples, stress cracking
- **Polymers:**
  - Adhesives, elastomers, creep, stress relaxation, dynamics, damping
- **Composites & Composite Engineering**
  - Light weight structures, load members, antennas, smart materials
- **Fasteners:**
  - Selections, installation torques, preload calculations, thread locking
- **Dimensional Stability:**
  - Long term creep, accelerated aging, CTE analyses
- **Thermo-Optical Coatings**
  - Thermal control, RF reflectance, deposition technologies
- **Radiation effects on materials:**
  - Materials selection, particle type dependency, total dose survivability
- **Failure Analysis / Tiger Teams**
  - Review boards, applied diagnostics & problem solving, teaming with other groups



Composite antenna



Coating chamber



Radiation damage



## M&P Group Activities

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- **Project support:** M& P Control Plan, MIUL, MUA, Waivers
  - **Materials selection:** polymers, metals, platings, thermal control coatings, primers, composites, ceramics, adhesives, fasteners, rivets, lubricants, insulators, corrosion effects, welding, charged particle and radiation effects
  - **Materials trade studies:** mass, strength, strain, thermal conductivity, electrical conductivity, radiation survivability, service life calculations
  - **Materials testing recommendations:** ASTM, ASME, MIL-STD, test data analysis
  - **New materials development and R&D functions**
  - **Qualified materials and processes:** flight accepted practices, maintain database
  - **Qualification of new materials and processes, add to database**
  - **Failure analysis and re-design of failed parts**
  - **Alerts and GIDEP tracking (database)**
  - **Administrative/Project:** CTM and CogE functions, Tiger Teams, Proposal preparation, drawing sign-offs
  - **See us early in your project: this will save us having to replace materials later**
    - Cost effectiveness: M&P usually cost about 3% of any major project
  - **Tutorials, databases and photos of our staff, expertise and phone numbers available on our JPL website: <http://materials/>**
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## Materials & Contamination Group



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- M&P Qualifications: 12 staff, about 1/3 each of Ph.D. /MS/BS degrees (conforms to JPL distribution)
  - Disciplines: metallurgy, composites, polymer science, chemistry, FEA, CAE/CAD
  - Activities: trade studies, failure analysis, stress analysis, testing evaluation, design, Laboratory tutorials, Laboratory standards
  - Bonding Classes: Jennifer Knight maintains the skill set in critical bonding operations and certifications for technicians at the Laboratory
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# Predictive Glass Fracturing



- Kristen Sutherland: “An Engineer’s Guide to Refined Glass Strength Forecasting”, AIAA 2009, best paper in Section
- Start with classic Weibull equation:
- Expand and test:

$$P_s = \exp \left[ - \left( \frac{\sigma}{\sigma_0} \right)^\lambda \right]$$

### C. Transformed Weibull

Substituting Eqs. (5) and (6) into Eq. (4), we find the transformed Weibull CDF shown in Eq. (8), which fully defines the relationship between survival probability and applied stress for the application conditions. When using the fatigue factor to transform the Weibull CDF from the laboratory conditions to the application conditions, the applied stress variable  $\sigma_{app}$  represents the maximum applied stress over all load types,  $\sigma_{max}$ .

$$P_{s,app} = \exp \left[ - \frac{S_{app}}{S_{lab}} \left[ \frac{\sigma_{app,max}}{\sigma_{0,lab}} \left( \frac{t_{eff,app}}{t_{eff,lab}} \right)^{\frac{1}{n_{lab}}} \right]^{\lambda_{lab}} \right] \quad (8)$$

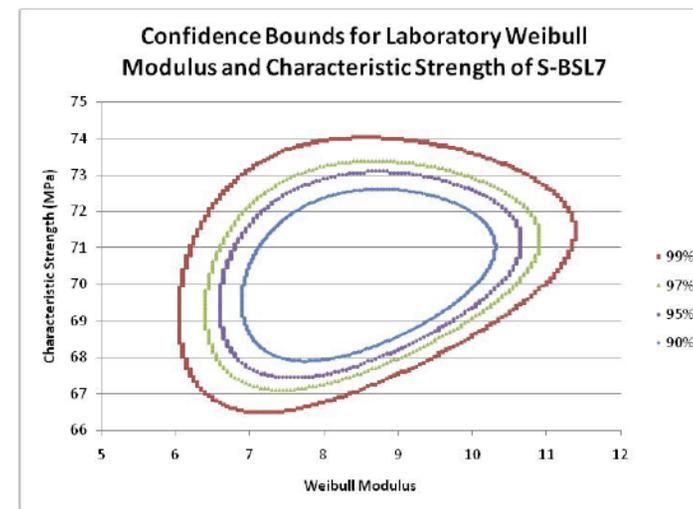
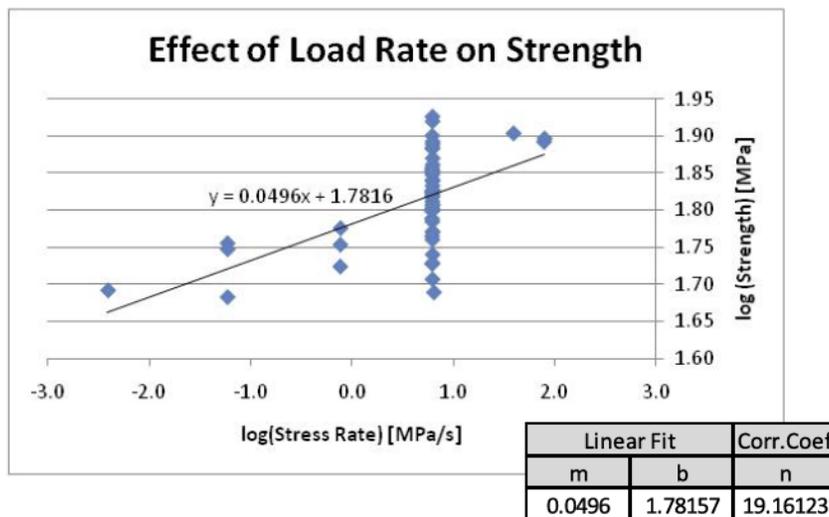
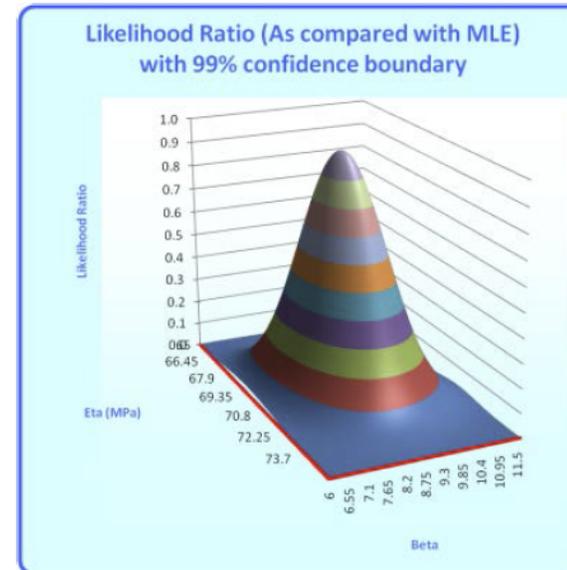
Equation (8) may seem daunting, but recall that many of the parameters are laboratory determined, and will be replaced with constants before analysis is completed by the engineer.

- Results provide more accurate assessments of fracture strength, design margins, reduced risk and lower mass in optical components
- Results directly applicable to the Space Interferometry Mission (SIM)





# S-BSL7 Glass Fracture Results

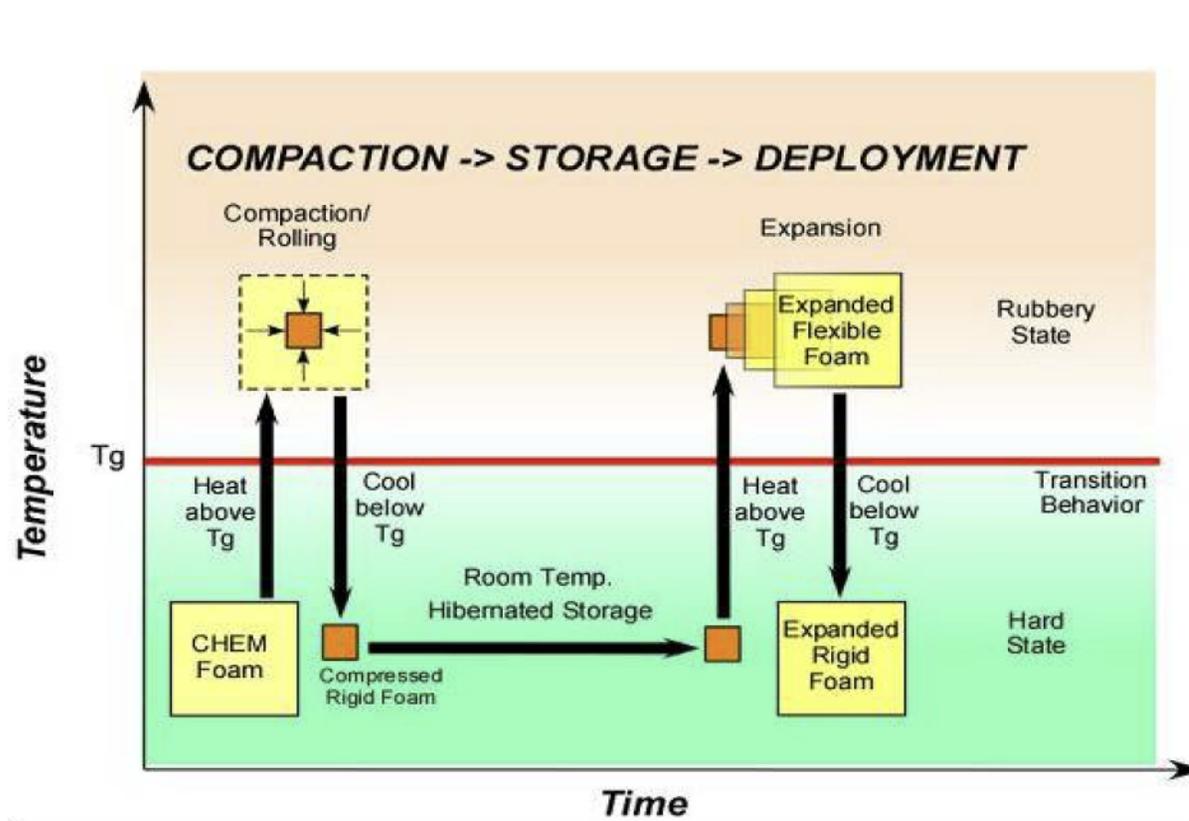




## Cold-Hibernated Elastic Memory Foams



- **Witold Sokolowski:** mainly metallurgy, but also expertise in shape-memory polymers and deployable structures
- **Concept:** Compress polymer foam, “freeze” below  $T_g$ , launch, and then heat above  $T_g$  again. Restoring force results in deployment
- **Uses:** solar sails, deployable trusses, deployable antennas





# Flight Fasteners

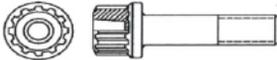


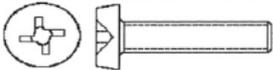
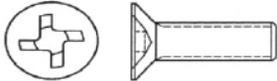
- **Don Lewis:** Metallurgy, failure analysis, design, platings, stress analysis
- **Fastener training course:** Serve as resource to Laboratory with expertise in fastener selection, running torques, nut factors, lubrication, English/metric conversions, alloy selections and high temperature materials
- **Maintains:** JPL fastener database
- **Mentoring:** Trains early career staff



## Spacecraft Fasteners



- A286 Fasteners (metric)
  - Spline Drive: NA0059 or STM12305  

  - Socket Head Cap Screws: NA0069, STM12307 or ST12407E  

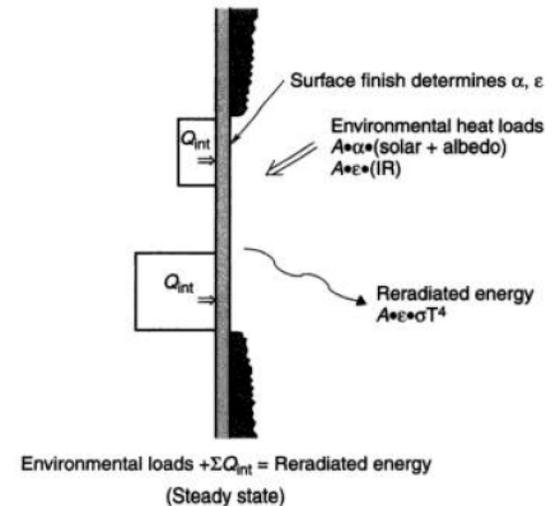
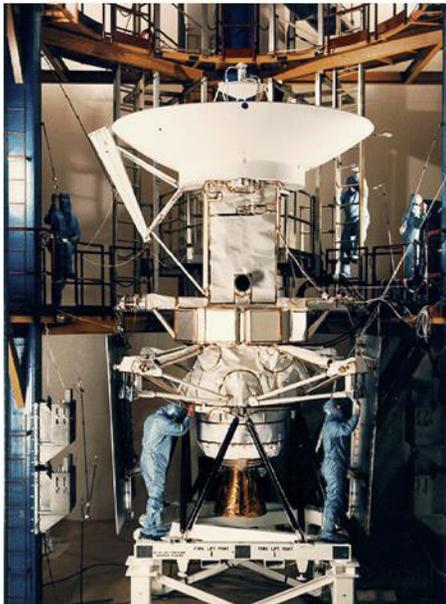
  - Pan Head Screws: NA0068 or STM12306  

  - Countersunk Head Screws: NA0070 or STM12308  




# Adhesives and Thermal Control Coatings



- **Jennifer Knight:** Lead engineer in these two critical areas. Maintains hands-on expertise in thermal control coatings and teaches the Flight Adhesives and Bonding course. Certifies the flight technicians.

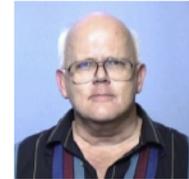




## Engineering Standards



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- **Gus Forsberg/Paul Willis:**
  - **Current documents owned: 260**
  - **Published and maintained online in the Project Data Management System (PDMS)**
  - **Topics: adhesives, thermal control coatings, surface cleaning, bonding processes, tutorial preparation, mentoring**





- **Contamination can degrade the performance of many spacecraft and payload systems:**
    - Solar arrays—loss of power
    - Thermal control surfaces—increased solar absorptance, emittance
    - Electro-static discharge effects—corona discharge
    - Optical systems—reduced throughput, increased stray light, degraded signal/noise
    - Noise in electrical contacts
    - Failure of precision mechanisms
  - **Many of these effects can impact terrestrial-based systems as well**
  - **To mitigate the risk to mission performance, it's important to understand sources contamination and the effect they have on contamination-sensitive system elements; devise appropriate—by mission phase—controls**
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## Contaminant Sources: Ground Processing



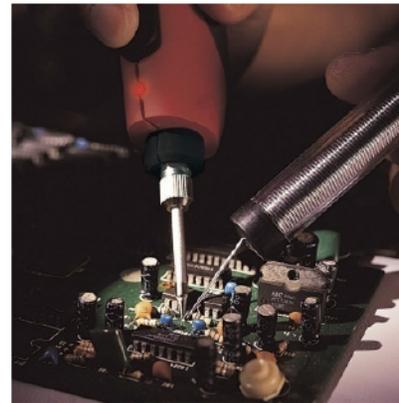
- **People:** finger prints, skin, hair, fibers
- **Processing:** machining chips, oil, sanding, drilling, trimming, paint chips, etc, etc
- **Room Air:** airborne hydrocarbons and particles
- **Tools and equipment:** dirt, grease, corrosion products
- **Uncontrolled environments**
  - Machine shop;
  - Transport between facilities;
  - Environmental test areas
  - Test chamber “anomalies”



People, clothing, materials



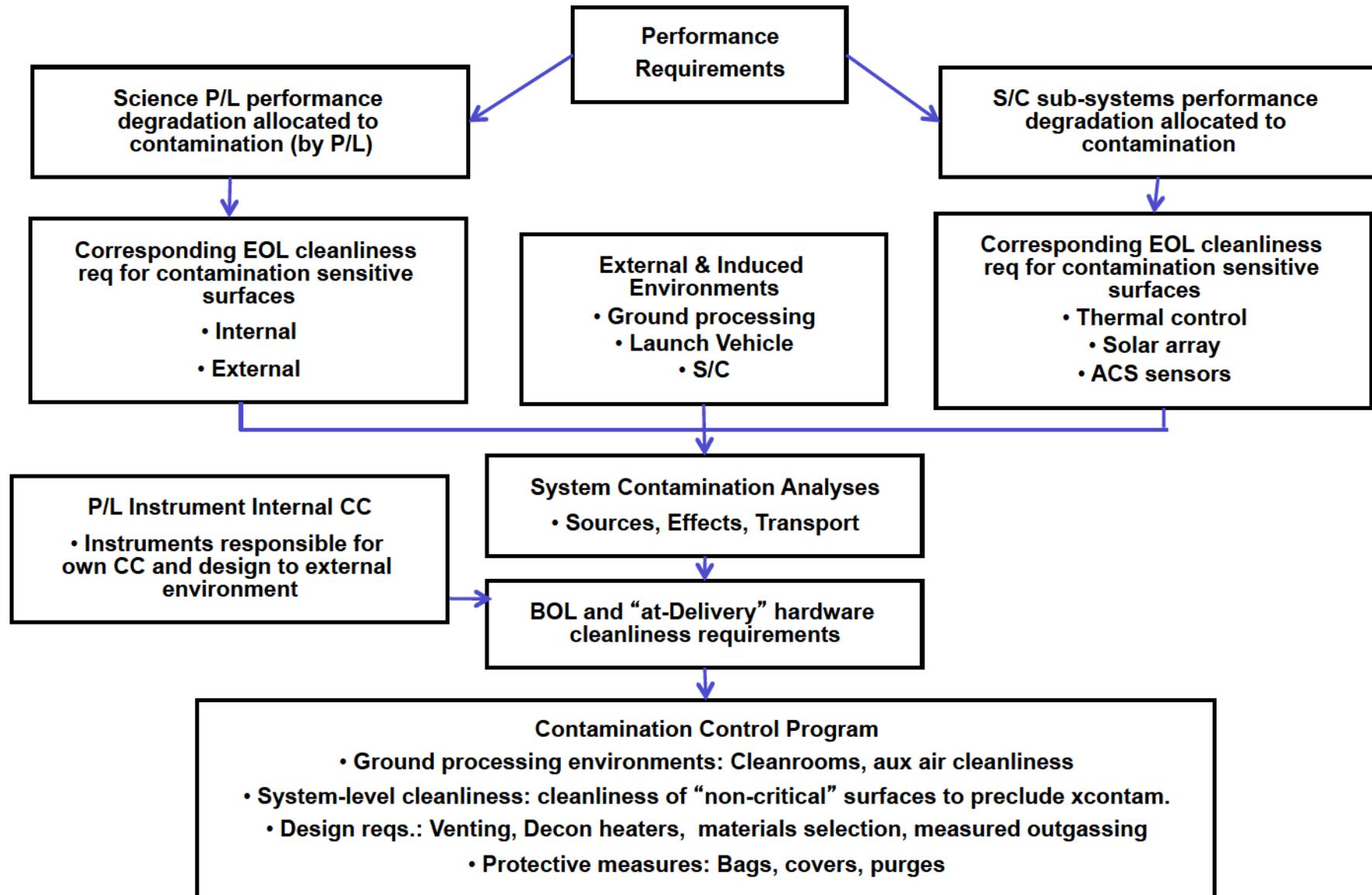
Machining



Working activities: soldering



# Contamination Control: Flow Process





## Materials & Contamination – Materials, Contamination and Contract oversight (2 charts)

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- MSL (Mars Science Laboratory):
  - Juno:
  - NuStar:
  - SMAP
  - GRAIL:
  - OCO2: (Orbiting Carbon Observatory)
  - AMD (Advanced Mirror Development): large ground-based mirror testbed
  - SIM Planetquest:
  - Europa (OPFM):
  - Urey:
  - O3 (Occulting Ozone Observatory):
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