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Prospector XII – Space Solar Array Cost Reduction Workshop

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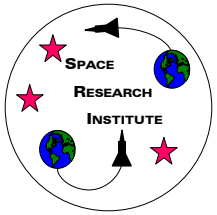

Outline

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- Prospector XII background
- Solar array orbital issues
- Workshop findings
- Recommendations

Prospector XII Workshop

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- Facilitated by Auburn University
  - Held in Park City, Utah, September 26-28, 2006
  - Sponsored by NASA-MSFC
- Attendees:
  - Solar cell and panel manufacturers, commercial and government satellite suppliers, NASA and USAF representatives and academia
- Prospector XII goals:
  - Determine the major drivers of spacecraft solar array-related costs
  - Make recommendations of steps to reduce these solar array-related costs

Workshop Topics

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- Topics examined:
  - Solar cell fabrication and array assembly
  - Solar array failures on-orbit and during ground testing
  - Impact of insurance claims due to solar array “anomalies” and failures
- Presentations covered:
  - Results of industry-wide visits and discussions
  - In-space solar array issues and ground testing issues
  - Non-conventional solar array performance
  - Insurance industry study results
- Report will be issued as a NASA-CR

The Ideal Solar Array Cycle

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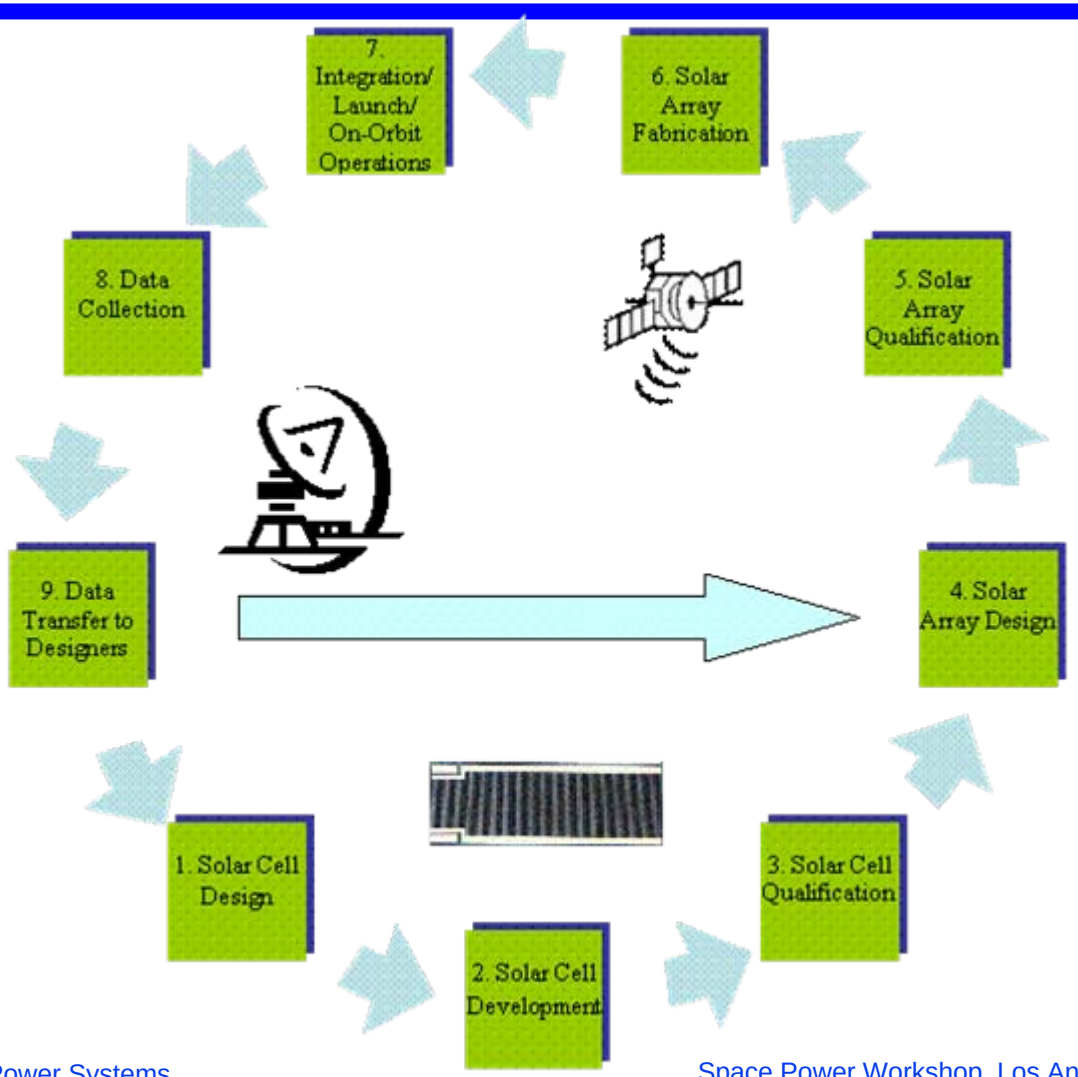

The Unfilled Cycle

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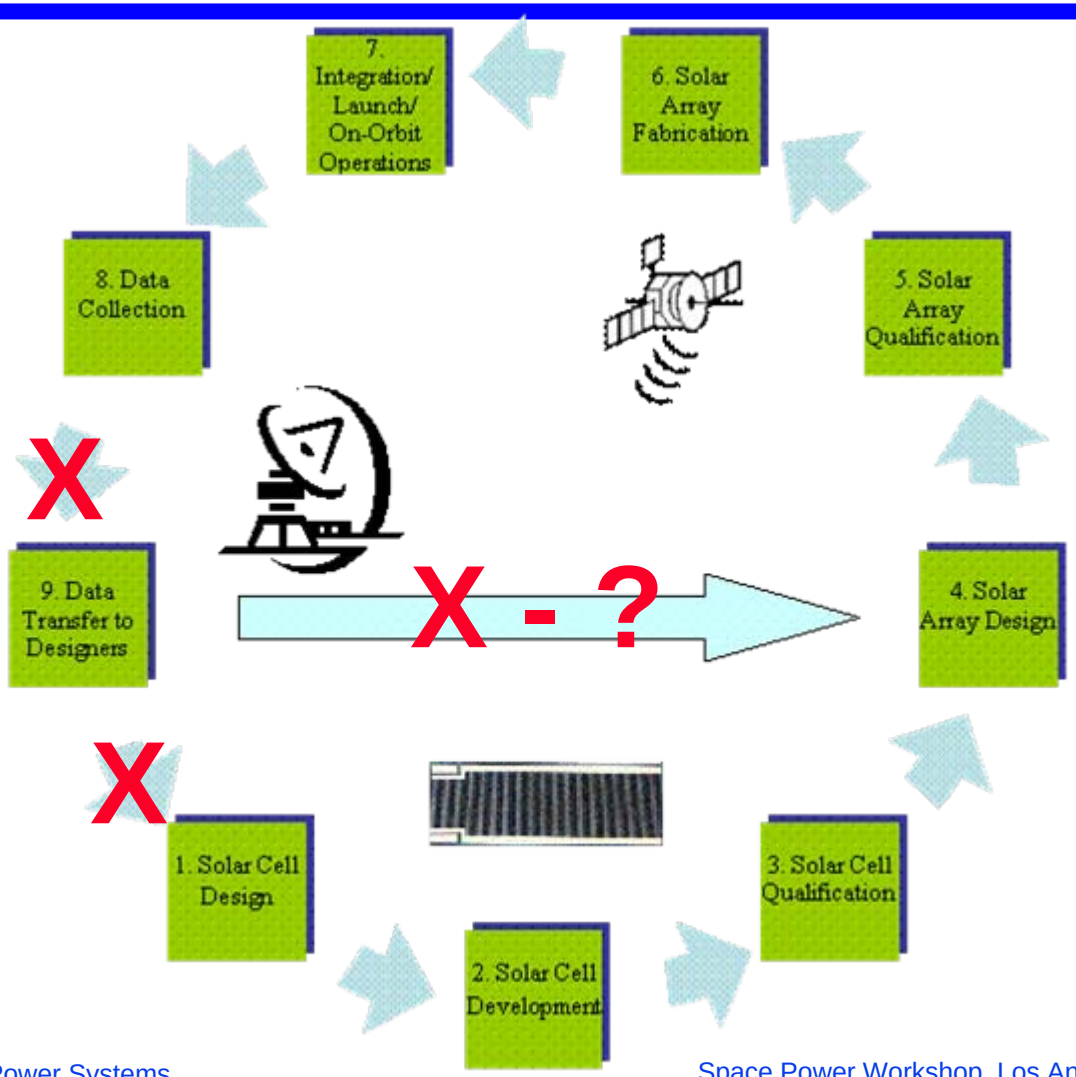

The Truth of the Matter

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- On-orbit satellite failures are continuing
- Over the period of 1999-2003, insurance claims made to one insurer exceeded $800M
- Overall in the insurance industry, claims exceeding $2B have resulted from satellite losses over the past six years
- Most of these claims were related to power system failures
- Solar array claims are involved in ~50% of those claims (from one insurer)
- Compromises the ability of some satellites to provide their contribution to national security

Insurance Claims Data* (~2004)

(Analysis of current data shows the same trend)

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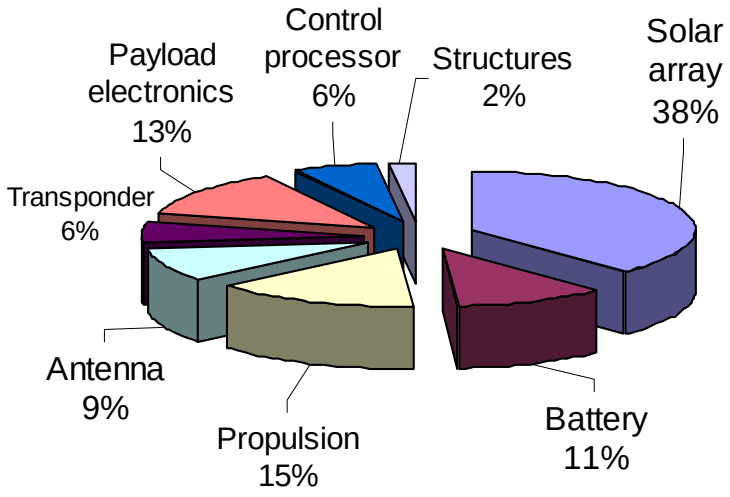
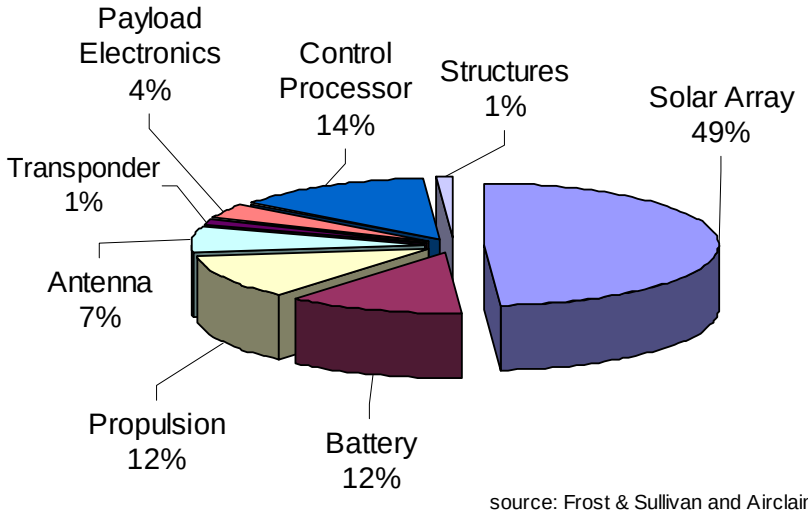
Number of Claims by Anomaly Type



source: Frost & Sullivan and Airclaims

Value of Claims by Anomaly Type



source: Frost & Sullivan and Airclaims

* P. Lecointe, SPW 2005

It's obvious that solar arrays and the power system are major problems

Solar Array Anomalies by Orbit

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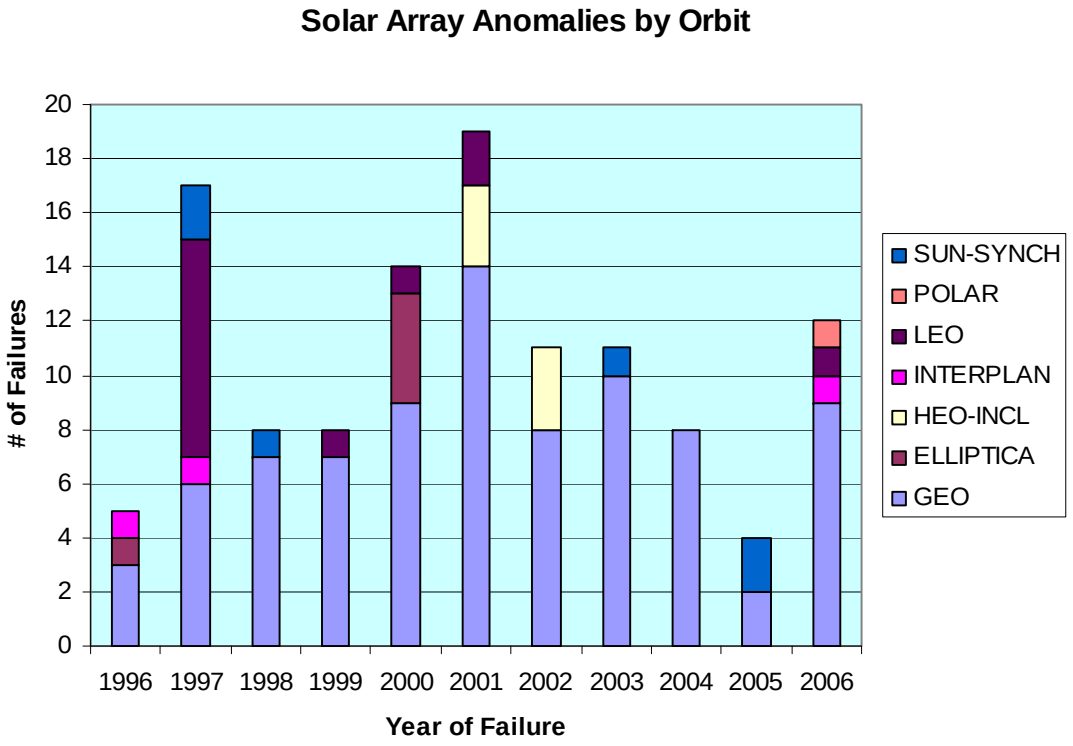
- Used Airclaims' "SpaceTrak" data base:
  - Between 1996 and 2006, 117 satellite solar array anomalies have been reported
  - 10 satellites have been retired due to solar array failure
  - Eighty-three of these reported anomalies and failures occurred in GEO (71%)
  - 2006 shows solar array anomalies increasing



What is a Solar Array Anomaly?

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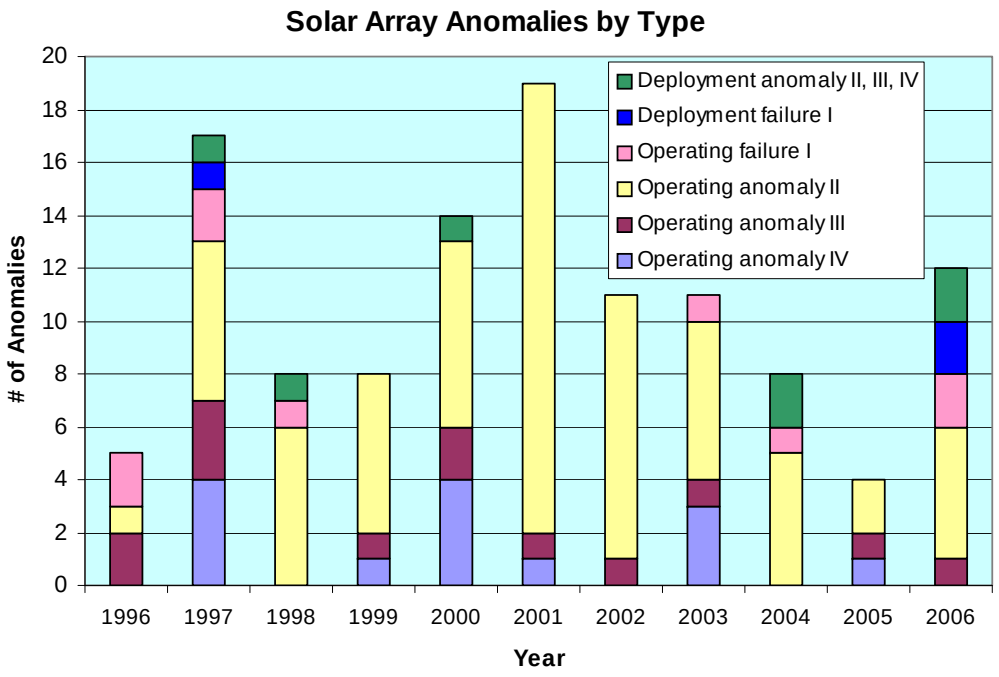
- Definitions of “anomalies”:
  - Deployment or operation (launch separate)
  - Type I, II, III, or IV
- Type I – complete failure
- Type II - non-repairable and affects the operation on a permanent basis
- Type III - non-repairable, causes lack of redundancy to the operation on a permanent basis
- Type IV - temporary or repairable and does not have a significant permanent impact on operation



Solar Array Anomalies over Time
(Matches classic infant mortality profile)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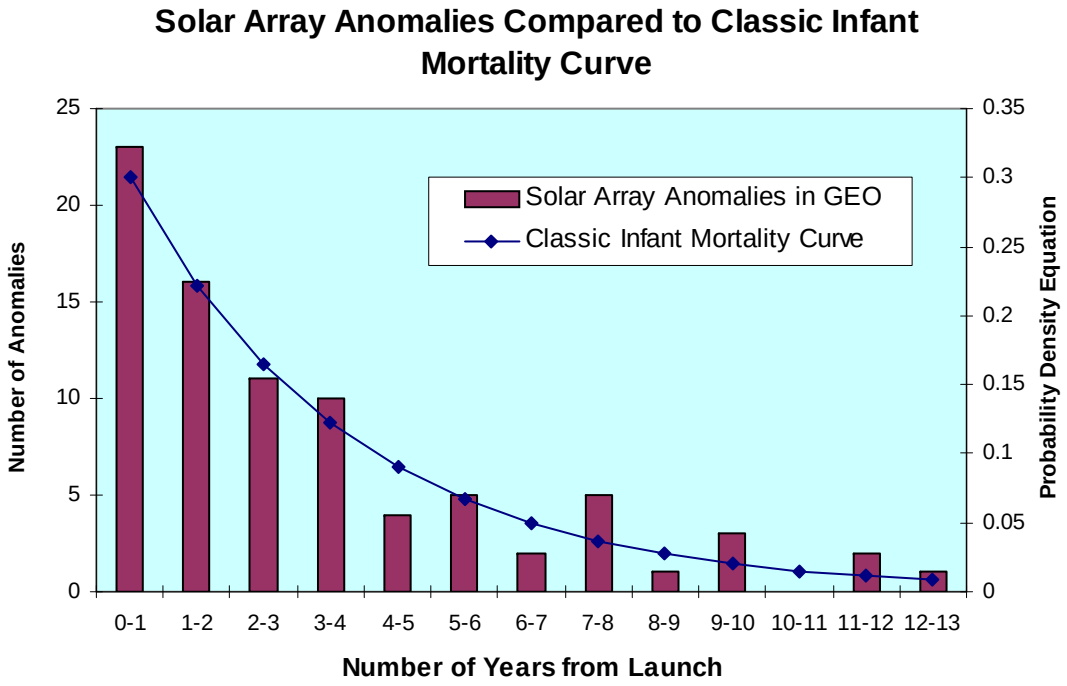
- Years between launch and anomaly in **GEO**
- Classic infant mortality curve suggests either:
  - Poor design, or
  - Defects in construction
- Indicates fundamental array issues
  - Not specific to any manufacturer
  - Therefore defects in construction are an unlikely cause



Typical Solar Array Problems

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- Electrostatic discharge
- Solder fatigue
- Strings shorting
- Welds failing
- Insulator too thin
- Expansion coefficient mismatch
- Overheating
- Cover glass darkening
- etc, etc, etc…

- These problems occur throughout the entire satellite industry **NOT** with just a few select suppliers and manufacturers
- And no one company talks to another to share experiences and thus lead to the benefit of eradicating the problem

Satellite Industry Issues

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- Critical need for reliable solar arrays
  - Reversing the increases in insurance costs
  - Increase confidence in commercial satellites
- Solar arrays are being viewed as high risk items
- Competitive pressure to reduce cell, module and blanket costs have led to razor-thin profits
  - Industry alone cannot justify improved equipment and process controls due to a long pay-back period
- Failure to fix existing design shortcomings is a potential source for continuing future orbital failures

Cost Avoidance Findings

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- Limited ways to reduce the cost of cell, CIC, or module
  - Materials costs in the cell dominate (e.g. Ge substrate)
    - Industry profits are squeezed by competitive pressures
    - Government support needed to automate
      - Industry can't justify investment based on pay-back time
  - Making the blanket and array more durable and reliable for the intended orbit appears sound
    - Cost effective yet with acceptable profit margins
- Major solar array cost reductions are best achieved by:
  - Making array reliability improvements
  - Examine new concepts that both reduce cost and may be inherently more reliable by design
  - Demonstrate solar array durability in terrestrial testing
    - Standardization of facilities and procedures

Recommendations

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- Increased array reliability is the best approach to cost reduction
  - Cell/CIC producers' profits are now squeezed near the limit
  - They cannot afford to automate due to long pay back time
    - Government support may be essential to implement
- Increase sharing of array data/problems across the industry
  - Informally or in called meetings by sponsors
  - Shouldn't compromise perceived competitive advantages
- Implement new testing requirements
  - AIAA standards for cells (S-111-2005)
  - AIAA standards for arrays (S-112-2005)
  - Should lead to increased solar cell and solar panel quality
  - Should not significantly increase costs (tbd)

Recommendations (cont'd.)

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- Create a certified module and array testing laboratory
  - Akin to the Underwriters Laboratory for electrical appliances
    - Will certify reliability of anyone's design in confidence
    - Use best ground test facilities and approaches
  - Can reduce costs to array manufacturers
- Install solar array on-orbit diagnostic instrumentation
  - Will help determine the root cause of orbital failures/anomalies
  - Limited information available now (e.g. string open or shorted)
  - Supports new AIAA standard S-121-2006
    - Includes a requirement for full I-V curve instrumentation
    - For launches 4-6 years in the future
  - Should lead to developing arrays with increased reliability

Recommendations (cont'd.)

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- Reexamine the use of "Heritage" as array criterion
  - Can be misused – may have led to on-orbit failures
  - Doesn't allow improved technologies to enter the marketplace – "I'll stick with what I have used"
- Seriously examine emerging array designs
  - Some appear to offer the potential for lower cost
    - Plus increased reliability for LEO to GEO applications
  - Need to be demonstrated in relevant orbits
    - Limited opportunities at this time
- Update the venerable "Solar Array Design Handbook" by Hans Rauschenbach
  - With modern cells and designs
  - What about future improvements in array designs?

Conclusions

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- On-orbit solar array failures are continuing (2006 was a bad year)
  - Solar arrays and power systems are causing most claims
  - Root cause determination hampered by lack of instrumentation
- GEO solar array anomalies match an “Infant Mortality Profile”
  - Problems appear to be industry-wide – suggests basic design flaws
- Lack of sharing of array problems between companies appears to be impeding progress
  - Past problems are being rediscovered (brain drain?)
  - Emerging AIAA standards should lead to industry-wide benefits
- Solar array cost reduction approaches limited
  - Increased reliability best approach, new concepts may help
  - Cell and CIC profits small now and are being squeezed more
- If you would be interested in attending a subsequent workshop on this topic please contact me

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QUESTIONS?