Introduction to ISO-11221, Space Systems – Space Solar Panels – Spacecraft Charging Induced Electrostatic Discharge Test Methods

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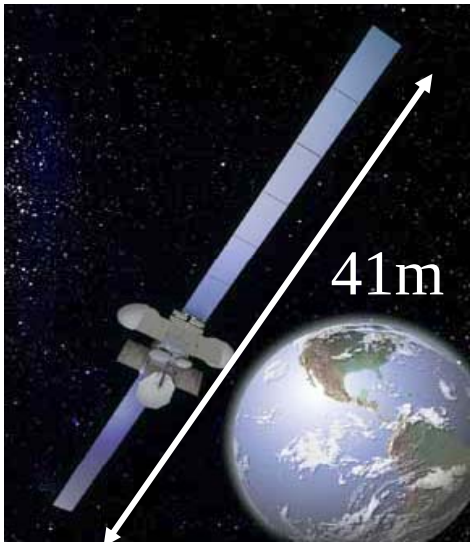
Introduction

www.spacedaily.com/ news/solarcell-02l.html



http://www.boeing.com/defense-space/space/bss/factsheets/702

Galaxy3C (2002)

Increased size of Geostationary commercial satellites

Increased number of transponders (>70)

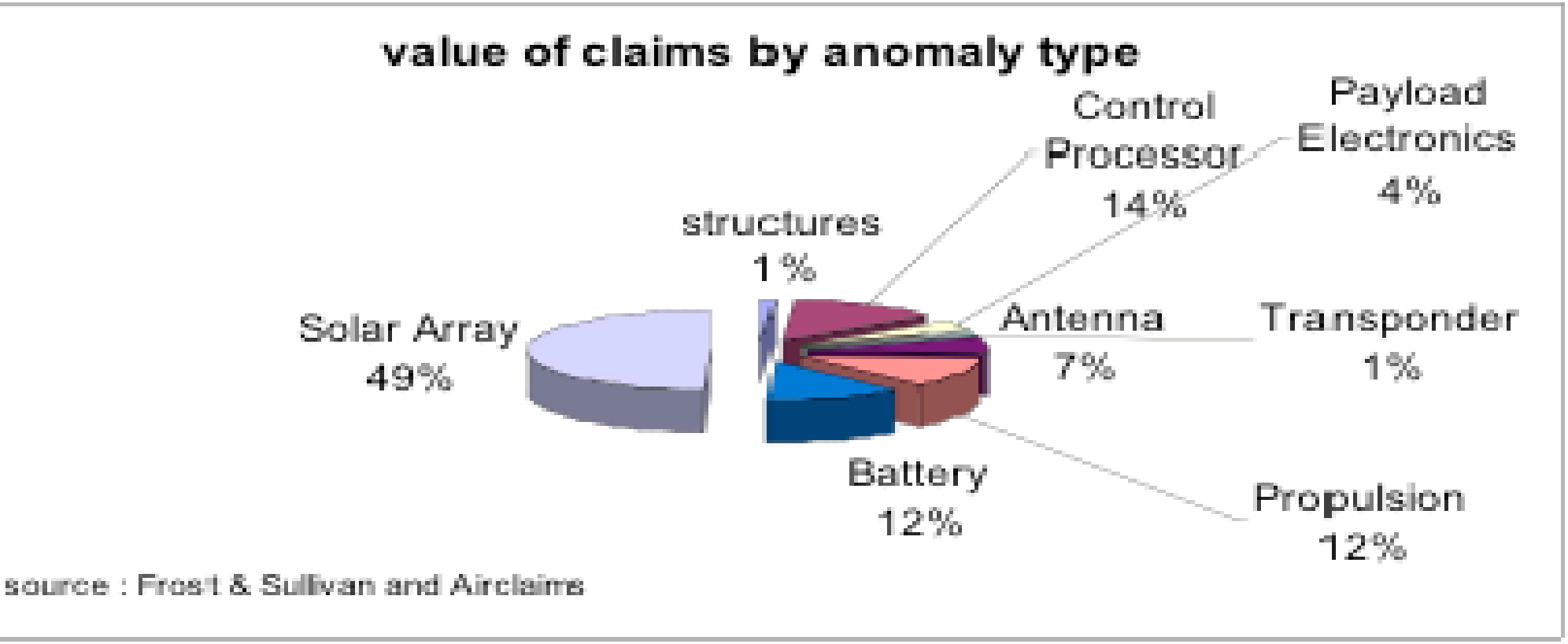
Increased satellite power(>10kW)

Increased satellite voltage

Use of 100V satellite bus voltage since the end of 1990s

Frequent satellite anomalies since the introduction of 100V bus

Introduction



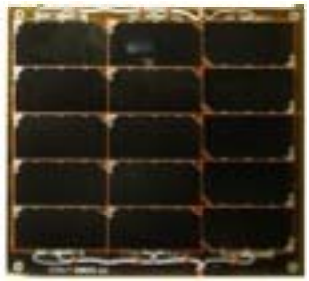
Statistics of 2004

Insurance payment was dominated by solar array failure

Introduction

- Internationalization of commercial satellites demands standardization of ground test methods

Component maker



Satellite manufacturer

http://www.ssloral.com/html/satexp/optusc1.html

Launch provider

http://arianespace.com

Service provider

http://www.dishtvsatellite.net/

Insurance company

http://www.kanagawa-nissan.co.jp/ucar/flow.html

They can be all different countries. What if something goes wrong in space?

Introduction

- Papers on GEO satellite accidents
  - Katz and Snyder, AIAA 1998-1002, 1998
  - Hoeber, Katz and Snyder, AIAA 1998-1401, 1998
- 7th SCTC (ESA-ESTEC, 2001)
  - Difference of test methods
  - Values of external capacitance
  - How to test, plasma or beam?

- 8th SCTC (Huntsville, 2003)
  - Round-robin discussion on standardization

Introduction

- Round-table discussion at 9th SCTC (Tsukuba, 2005)

9th SCTC

Mr. Eishima at 9th SCTC
ISO/TC20/SC14/WG1 Convener

9th Spacecraft Charging Technology Conference

- 124 participants, April, 2005

Resolution passed at 9th SCTC

Experts on spacecraft ESD ground test who participated in the round table discussion on ESD test at 9th SCTC have agreed

- to fully cooperate and make best efforts as experts to draft an ISO standard on solar array ESD ground test by 10th SCTC and **establish the standard within 3 years**
- to try to resolve disputes over the test methods by 10th SCTC

9th SCTC

April, 6, 2005

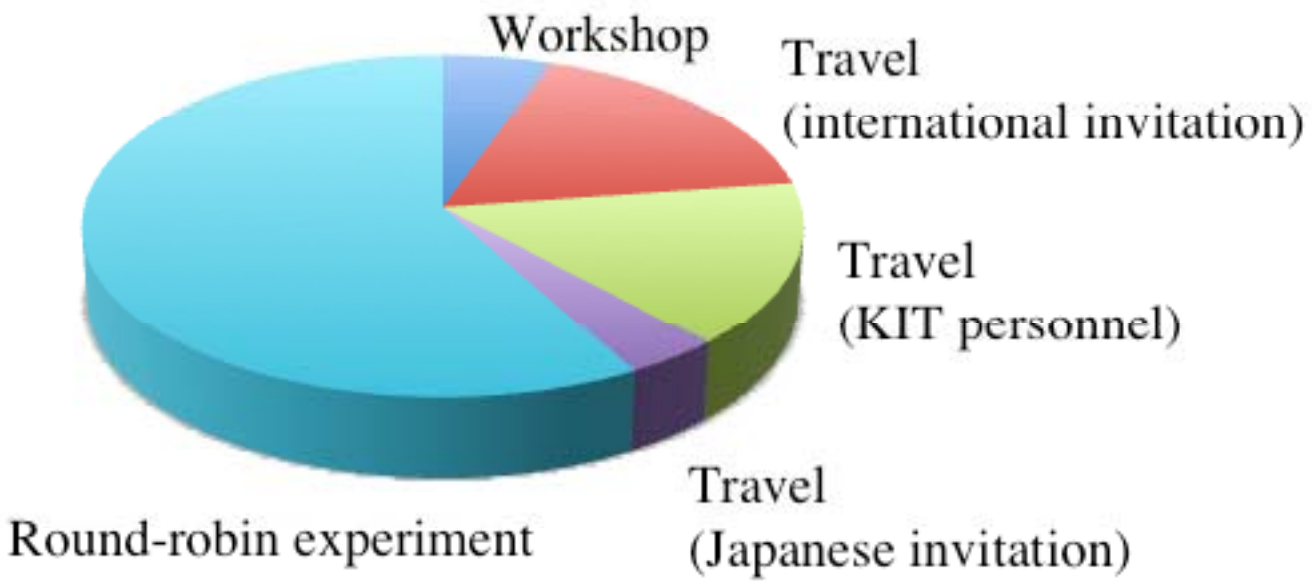
NEDO-grant research

- **ISO Standardization of Electrostatic Discharge (ESD) Test of Satellite Solar Array**
  - Sponsored by NEDO (New Energy and Industrial Technology Development Organization) International Joint Research Project
  - Subsidiary of Ministry of Economy, Trade and Industry
  - 3year project from October 2005 ~ September 2008
  - Participation of KIT, JAXA, Sharp, Mitsubishi Electric, NEC-Toshiba Space, ONERA, CNES, Thales-Alenia Space, Astrium, NASA, OAI
  - 70,000,000 yen (~$0.5 million that time)

NEDO-ISO Project Overview

- International round-robin experiment
- Mutual visit and workshop
- Drafting ISO standard

How the money was spent



Items to study

- How big is primary arc current?
- Solar cell degradation due to repeated primary arcs
- Test environment effects
- External circuit to simulate solar array power circuit
- Estimation of primary arc numbers in orbit

Workshops

1st, Nov. 2006, Kitakyushu, Japan

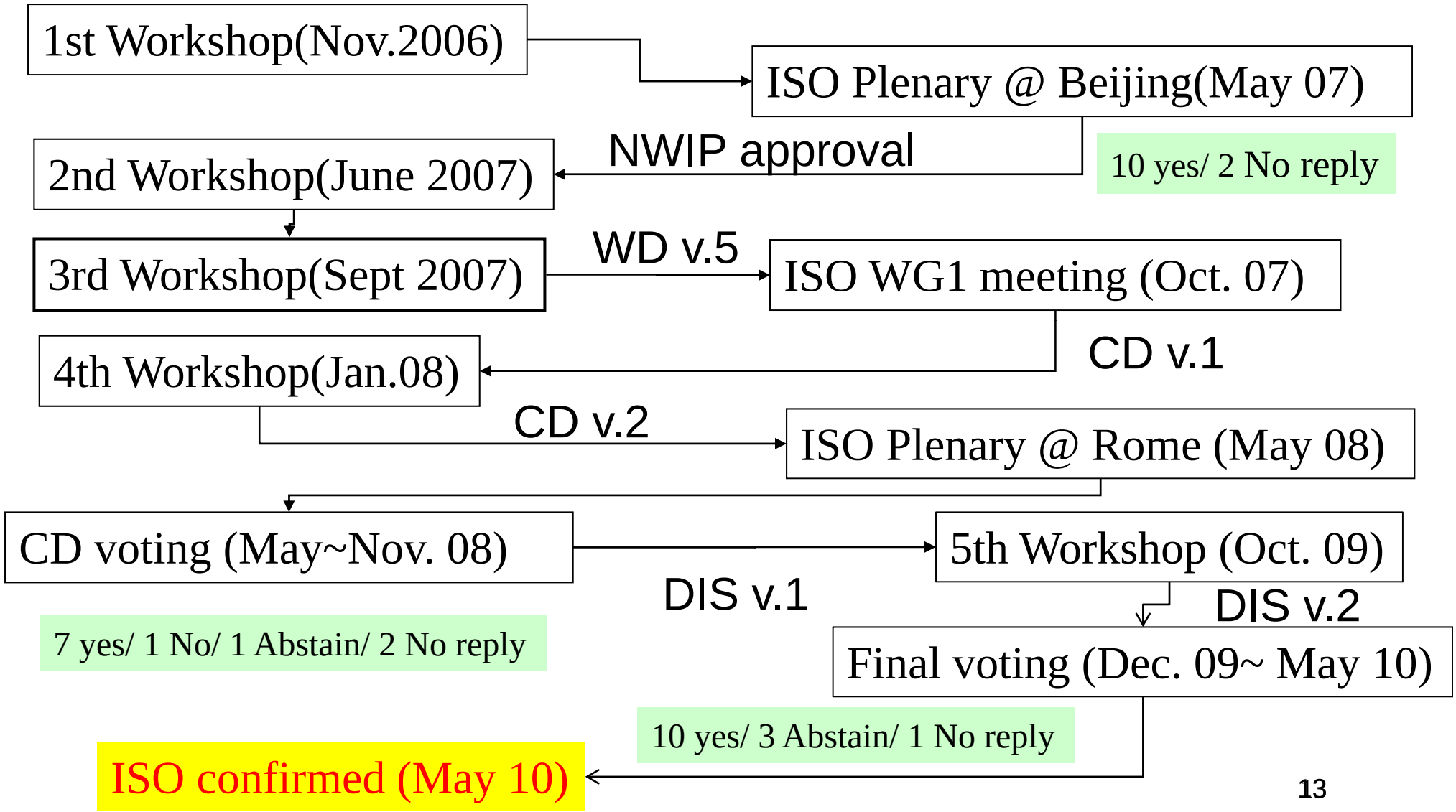
2nd, June, 2007, Biarritz, France

3rd, Sept.. 2007, Cleveland, USA

4th, Jan. 2008, Tokyo, Japan

5th, Oct. 2009, Kitakyushu, Japann

How did we go?



Finished from NWIP to DIS approval in 3 years!

Contents

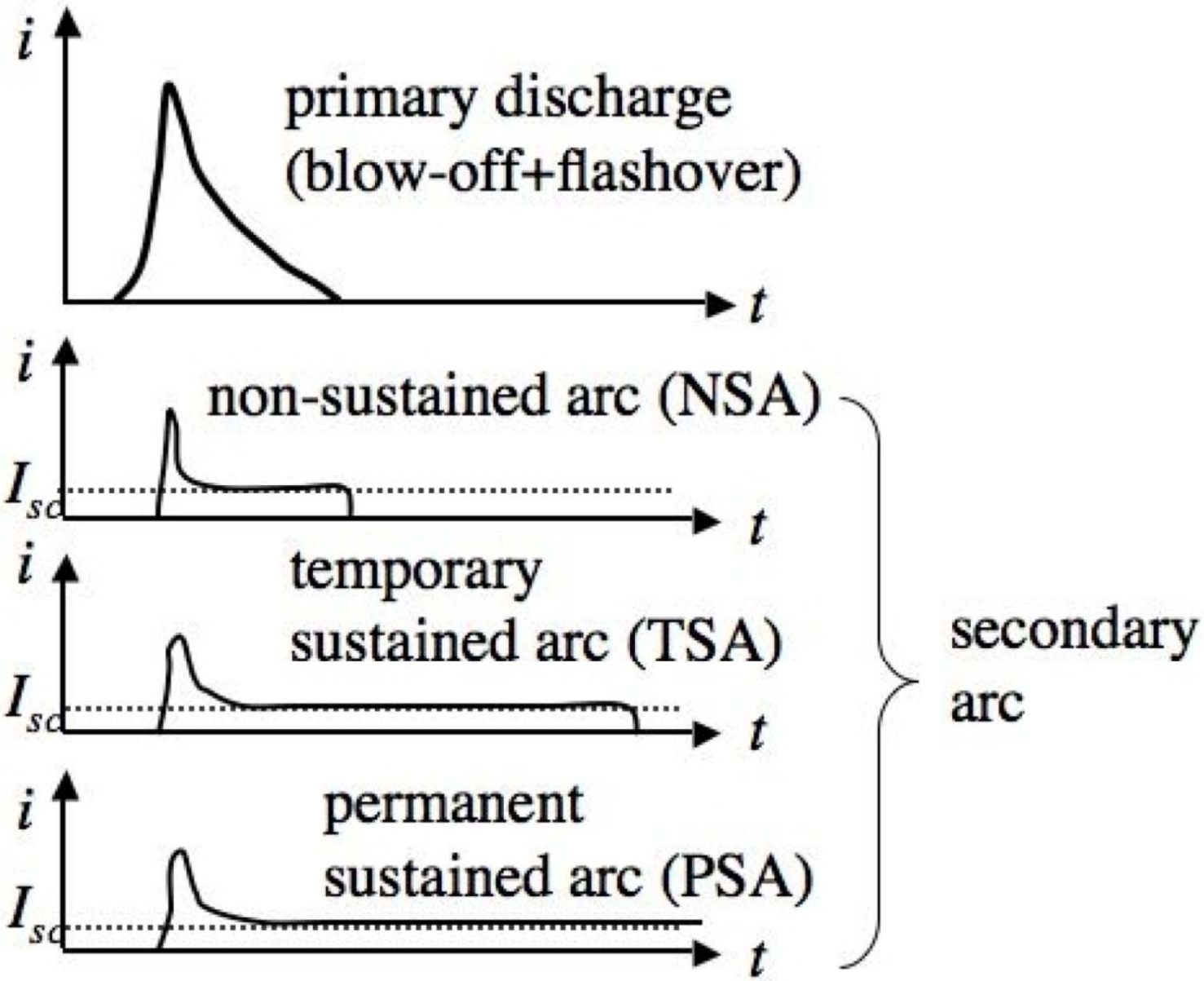
42 pages !!

You can download from ISO web site in 66 Swiss Franc (~66 US $)

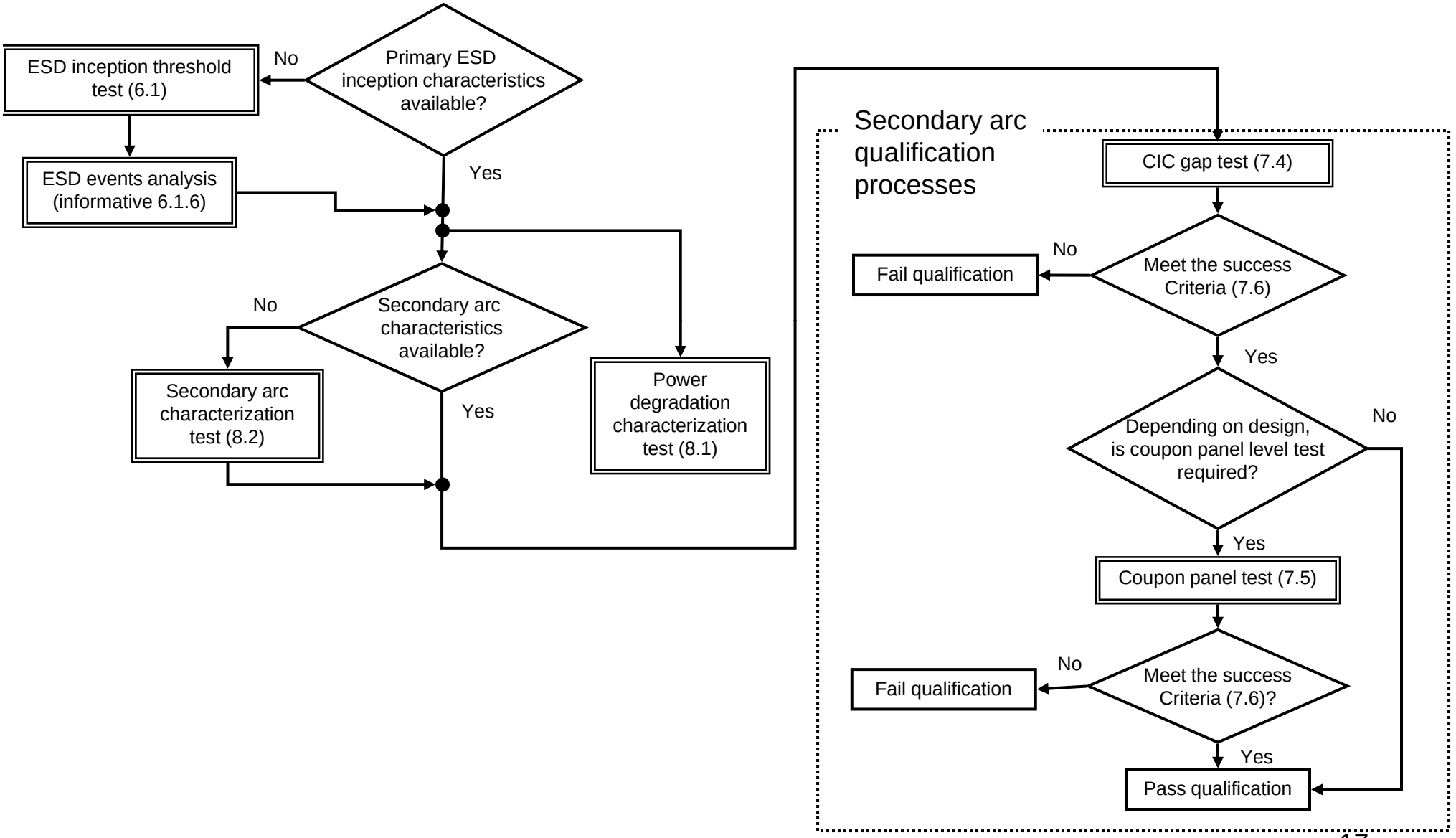
Scope

- This standard provides qualification and characterization test methods to simulate plasma interactions and electrostatic discharges on solar array panels in space. This standard covers solar array panels made of crystalline silicon, gallium arsenide (GaAs) or multi-junction solar cells. This standard addresses only surface discharges on solar panels.

Terminology



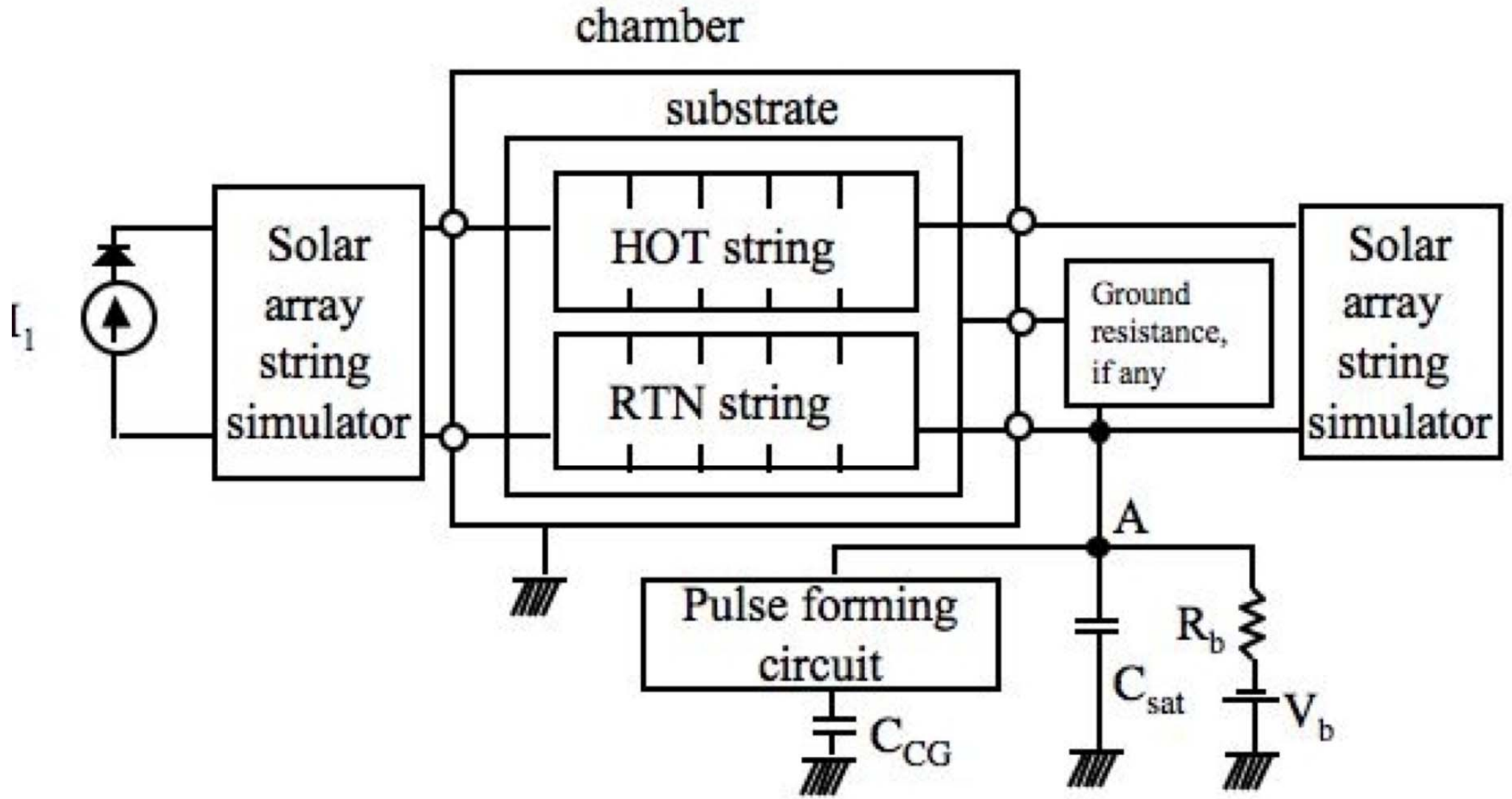
Test flow (secondary arc)



Test facility

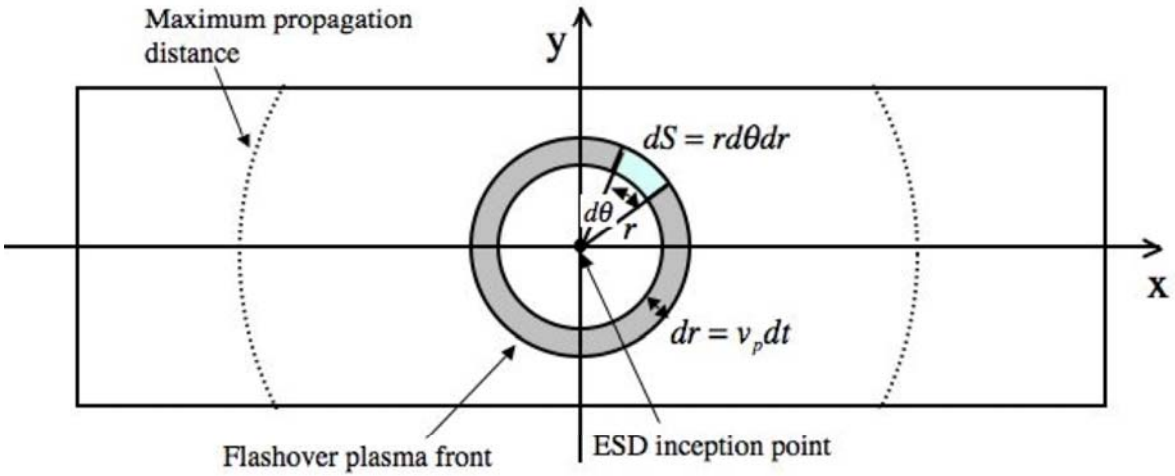
- If it can be confirmed that the probability of a transition from a primary discharge to a secondary arc does not depend upon the method of primary discharge inception, *any method can be used to cause primary discharges, irrespective of the anticipated charging situation in orbit.*
- The test shall take place under vacuum in a test chamber with a pressure that guarantees the physical state of a collisionless plasma if a low energy plasma is used, or lower than $3x10^{-3}$Pa if other triggering methods such as an energetic electron beam, UV ray, laser pulse, etc., are used.

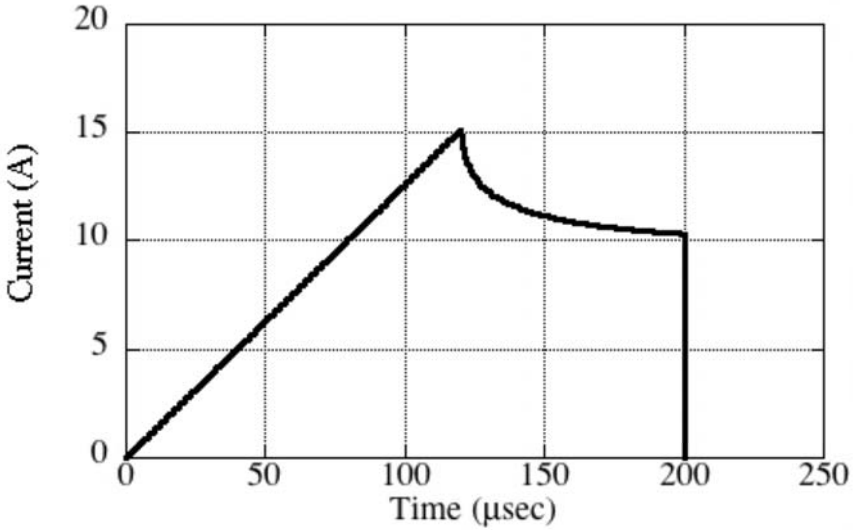
Secondary arc test



Flashover current

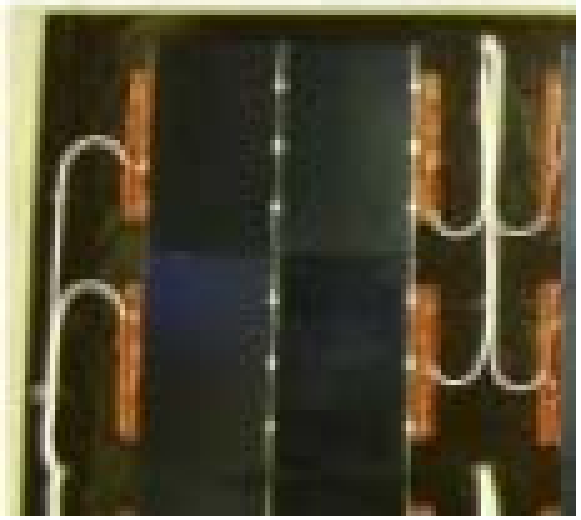
- The current waveform supplied by the external circuit shall be representative of the surface flashover current in orbit. The present state of knowledge about the propagation distance is two meter confirmed by a laboratory test using a 4mx1m coupon panel. The present best estimate of the propagation speed of surface flashover is 10km/s for a GEO solar array under inverted potential gradient.





CIC gap test

- The test coupon(s) shall consist of at *least two strings of two cells* to represent a point surrounded by solar cell corner edges.
- Concentrating the primary discharges on the cell gap is permitted. The test shall ascertain that a significant number of primary discharges (at least three, or the number more than three agreed with the customer based on statistical discussion. See Ref.[4] for an example) per given test condition occur in the active gap or the vicinity of the active gap if a grouted gap is tested.

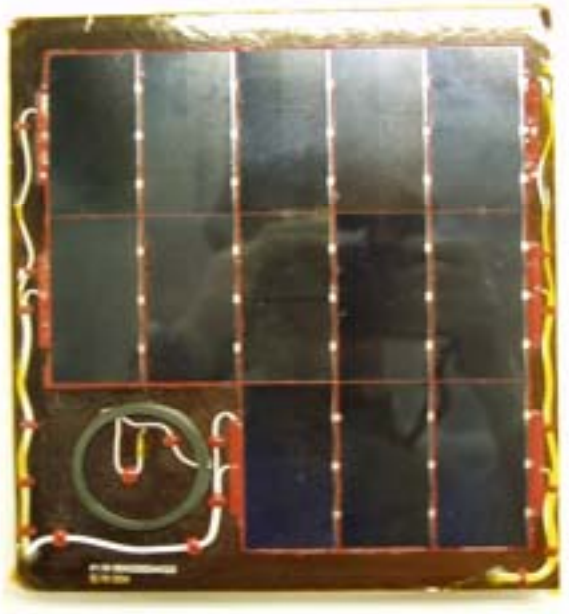


Assuming the worst case

Coupon panel test

- The test coupon shall consist of at *least three strings of three cells* to represent a cell surrounded by other cells. The coupon shall be a flight-representative qualification coupon covering the production variation of the string gap distance and CIC cell configuration (coverglass overhang, adhesive thickness, etc.) including reworked cells.
- The total number of primary discharges on the coupon shall be determined by a statistical analysis. *No control shall be done over the primary discharge locations.*

Test as you fly



Success criteria

- The test shall demonstrate that no damaging secondary arc occurs due to ESD

What to do next?

- Most standards require periodic revision. Several factors combine to render a standard out of date: technological evolution, new methods and materials, new quality and safety requirements. To take account of these factors, ISO has established the general rule *that all ISO standards should be reviewed at intervals of not more than five years*. On occasion, it is necessary to revise a standard earlier

(From ISO Web site)

Next steps

- Revision expected by the beginning of 2016
- Discussion on how we want to revise at 12th SCTC
  - Possibly Spring, 2012
  - Until then
    - Use the standard for actual tests and find problems if any
    - Carry out basic research
    - In-orbit study

Basic research items

- Aged coupon of secondary arc
- Circuit effect (Cext, inductance, Csat, …) on
  - Cell degradation
  - Secondary arc
  - Flight representative standard circuit set-up
- Flashover extension over 2m
- Flashover propagation model
  - Flashover simulator
- More study on degradation
- Combined test
  - Solar light, UV, high energy particles
- Effect of different chambers
- Degradation of new type cell
- Suppression of primary arc

Others

- Flight experiment on degradation
  - PASCAL on MISSE-8 (to be launched to ISS in Feb. 2011)
  - HORYU nanosatellite (to be launched in Nov. 2011)
- GEO experiment
  - Flashover distance
  - Flashover speed
  - Number of arc
  - Frequency of arc
  - Waveform of arc
  - Cell degradation
  - Demonstration purpose
- Design guideline

Acknowledgment

- **To everybody who contributed to this standard**
  - Thank you very much for your cooperation to establish this standard. Without the combined efforts by the community, this standard would never be possible.
  - Let’s work together for better standard to improve the reliability of satellites and make space something more usable.