Specifications of the GLAST Silicon Strip Detectors (SSD's)

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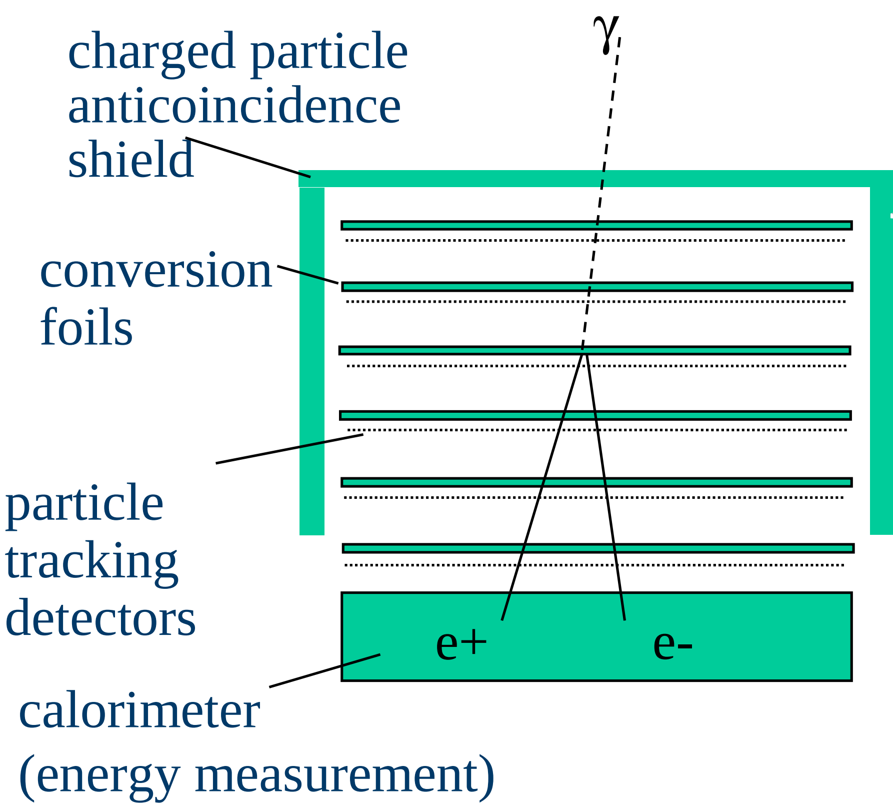
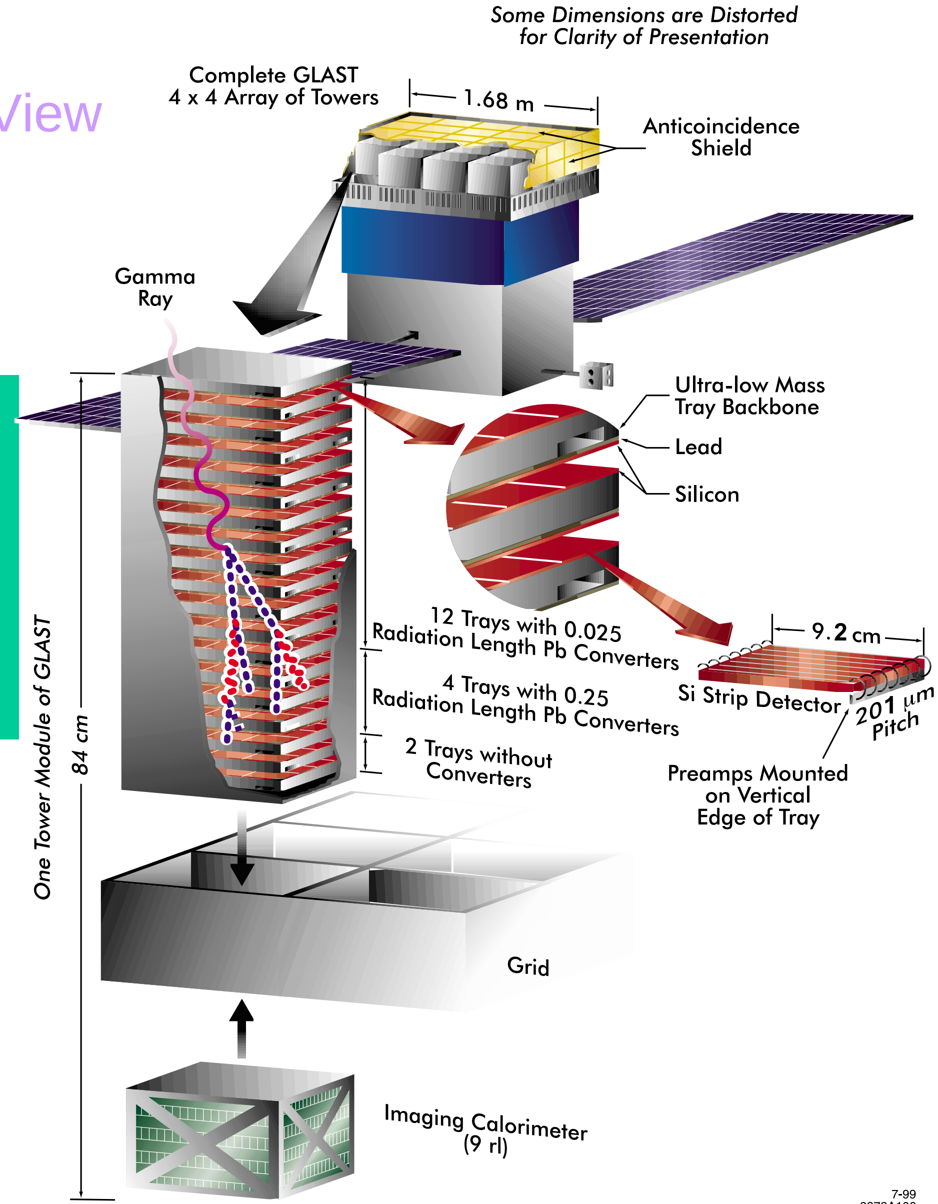
- GLAST Overview: Instrument -> Tracker (TKR) -> SSD
- Requirements
- Prototyping History
- Procurement History and Schedule
- Testing and QA
- Validation -> next talk (T. Ohsugi: electrical, A. Brez: mechanical, T. Handa: Irradiation)

GLAST LAT

Principle of Operation vs. Artist's View





GLAST LAT TKR

- **Numbers: GLAST is modular:**

  16 flight (+ 2 calibration towers) with 18 x-y SSD planes each

  4 x 4 SSD per plane (4 ladders with 4 SSD each)

  Number of SSD needed:

  10368 (+ 5% spares + 5% wastage) => 11,500
- **Total SSD Area: $83m^2$, ~1M channels, ~ 5M wire bonds**
- **Simple mechanical assembly method:**

  Butt-join and wire-bond 4 SSD to “ladders”

  Glue 4 Ladders onto both sides of 3cm thick panels (“trays”)

  Attach MCM on the side of the panel via 90^o interconnect

  Stack trays into towers
- **QA:**

  Tight specification increase reliability of SSD

  Charge manufacturer with all detailed testing

  Test important parameters before further integration step

Requirements for the GLAST SSD (1)

Science Requirements Document (SRD)

- **Derives the GLAST LAT instrument performance requirements from the GLAST science objectives.**
- **Sets requirements and goals for several instrument parameters, e.g.**

Effective Area = (Active area * conversion probability * reconstruction efficiency)

Point Spread Function = Resolution in the photon direction

Cosmic Ray rejection

The science requirements flow down into the TKR and SSD specifications.

GLAST LAT Committees on TKR issues:

- **SSD Configuration : April/May 2000 (“GLSSDWG”) LAT-TD-00070**
- **Converter Optimization: June/Nov 2000 (“GTOCC”) LAT-TD-00029-01**

These Committees specified the footprint of the instrument, the size of the trays, and the layout and size of the SSD, taking into account the SRD and the IRD (see next)

Requirements for the GLAST SSD (2)

Interface Requirements Document (IRD)

defines the Space environment and the limited resources, including engineering margins (e.g. 5x for total dose).

The IRD requires trades in:

- **Power**

  number of channels (SSD pitch),

  ASIC power consumption

  SSD strip capacitance (ladder length - ~36cm-, strip geometry),

  SSD biasing power <4W for 10k SSD

- **Radiation**

  Expected 5Y total dose 1kRad (half in low energy protons), design for 5kRad

- **Heat management**

  operate SSD at 25^{o}C max

- **Launch- weight, vibrations-**

  Footprint of SSD

  Strength of SSD wafers (<100>)

  Strength of glue joints

Issues for the GLAST SSD

The following issues were addressed in the GLAST SSD design ("GLSSDWG") and are reflected in the specification

Issue	Action	Reason
Leakage Current	Minimize	Power, Noise, μ-Discharge
Depletion Voltage	Minimize	Power, Safety, Efficiency
Detector Thickness	Optimize	Signal vs. Depletion Voltage
Saw-cut dimensions	Control	Mechanical assembly
Number of bad strips	Minimize	Efficiency, C.R. rejection
Strip geometry	Optimize	Capacitance vs. μ-Discharge
Mask Alignment	Control	μ-Discharge, Testing
Dielectric of Caps	Oxide+Nitride	Pinholes, Bondability
Radiation Effects	Measure	Leakage current, Capacitance, Strip isolation, Bias resistor
Guard ring/Edge design	Narrow	Leakage current, active area
Bonding/probe pads	Redundant	Repairs, Automatic Test
Fiducials	Dedicated	Ease & QC of assembly

Design Criteria for the GLAST SSD

Predictability of Performance

- Poly-silicon biasing
- Oxide-Nitride combination for coupling cap dielectric
- Low leakage current
- Low depletion voltage
- Silicon dioxide passivation
- Large Aluminum overhang
- Balance strip width effects: capacitance vs. field
- Accurate mask alignment
- No voltage across saw-cut

Ease of Testing

- AC coupling
- Large, redundant bonding/probing pads
- N-sub contact on top

Ease of Assembly

- Separate fiducials for alignment, bonding and metrology
- Accurate control of saw-cut

Justification of Key Specifications

Leakage Current: (av)<240nA , max<800nA

- The low detector leakage current is an indication of a mature manufacturing process.
- A low detector leakage current specification allows us to eliminate the time consuming leakage current measurement on every strip and measure instead the entire current on the detector only.
- The leakage current has to be kept low to reduce shot noise (35cm long strips!)
- Single detector strip with ~20nA has increased noise level.
- One of the major limitation for the GLAST LAT is the available power. The power assigned to the detector biasing is 4W at end of mission, mainly due to radiation damage.
- At 150V, this is 2.6uA/SSD, and the initial detector current should be a small fraction of this number.
- Because we observe a factor 2 increase of the leakage current from production testing to finished ladders, our specs mean actually an initial current of about 500nA/SSD, about 20% of the end of mission limit.

Justification of Key Specifications

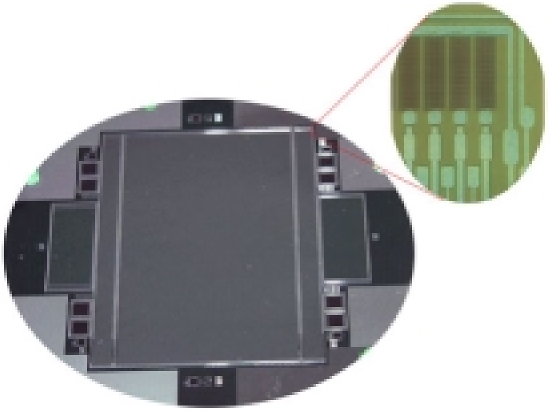
Detector Thickness: 400um

- The TKR has sufficient S/N as specified. The signal is proportional to the path length. For normal incidence, it's the thickness (400um), for large angles it's the pitch (228um). So if S/N is a problem, the pitch has to be increased as well, which hurts the science.
- The depletion voltage has to be kept low to reduce power and noise. We set an upper limit of 150V, but would like to operate at 100V (like in the BTEM).
- The depletion voltage depends on the square of the detector thickness

  and the inverse of the resistivity. Thus changing the thickness from 400um to 500um requires an increase in resistivity of 56%, from 4kΩ-cm to more than 6kΩ-cm. We are told that the wafer manufacturers can't guarantee a stable supply of 6" wafers with resistivity higher than 4kΩ-cm on our time scale.
- We see now depletion voltages at 120V, which would increase to 188V with 500um thickness at the same resistivity. This is too high.
- Our principle supplier prefers 400um detectors and fabricates (exclusively?) in that thickness. Mixing different thickness sounds like an assembly nightmare.

Procurement for the GLAST SSD

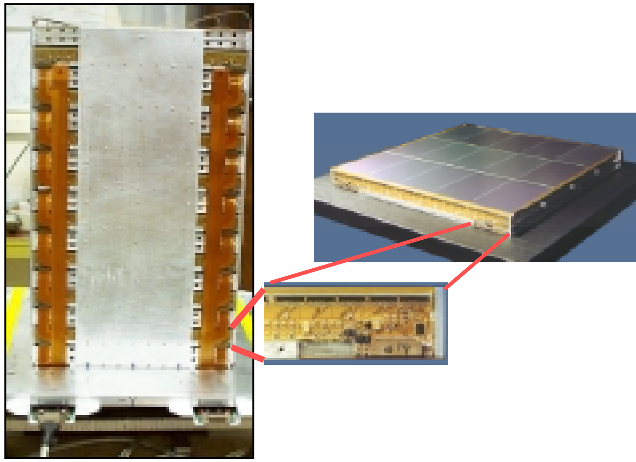
4 Step Procurement Process



1998: Market survey (RFI), contact 12 manufacturers
- -> 6” wafers
- -> Identify cost-drivers in fabrication and testing

1996-2000: Prototyping with 3 manufacturers, involve them in writing of specs

1998-1999: Purchase large number (>500) of SSD, build BTEM, 2 month beam test at SLAC



Fabrication and Test Plan of Flight Sensors:

prototyping	(Jun 2000 -- Dec 2000),
evaluation	(Dec 2000 – Jan 2001),
ramp-up	(Feb 2001 – Aug 2001),
production	(Aug 2001 – Mar 2003).

Prototyping of the GLAST SSD

Prototypes of GLAST SSD with Hamamatsu Photonics (HPK)

	GLAST 1996	**GLAST 1997**	**GLAST 1998**	**GLAST 1999**	**GLAST 2000**
Wafer Size	4”	4”	6”	6”	6”
Sensor Size[cmxcm]	6x6	6.4×6.4	6.4×10.7	9.5×9.5	8.95x8.95
Pitch [um]	236	194	194	208	228
Implant Width[um]	57	50	50	52	56
Thickness [um]	500	400	400	400	400
Biasing	Punch Through	Poly-Si	Poly-Si	Poly-Si	Poly-Si
Bias Voltage [V]	140	100	100	100	100
Current [nA/cm^2]		~2.5	~2.5	~1.8	~1.8
% bad strips		0.02	0.04	0.04	0.03
# delivered	~20	296	256	35	35
Use	BT’97	BTEM	BTEM	<100> Wafer	Acceptance

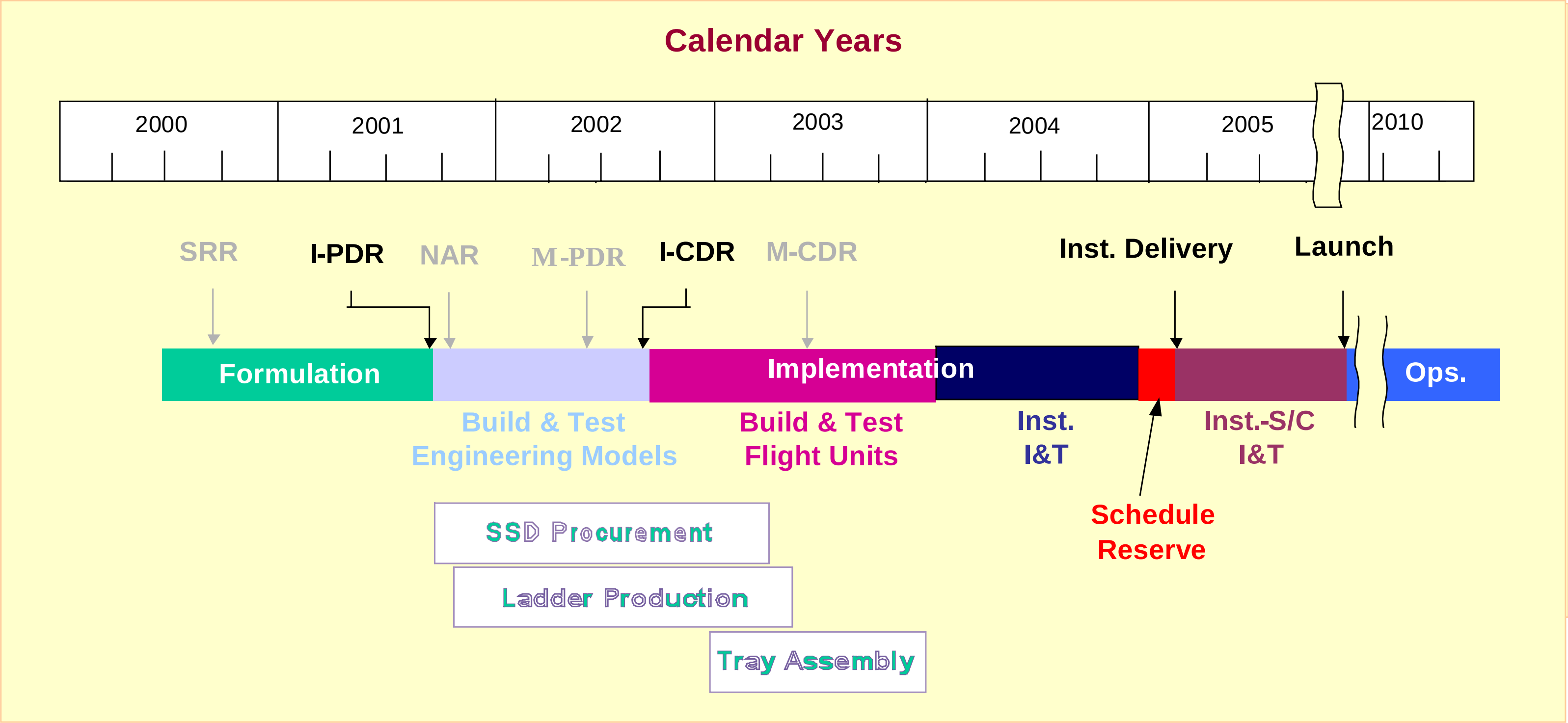
We have gained experience with a large number of SSD (~5%of the GLAST needs)

Additional Prototypes:

Micron (UK), STM (Italy), CSEM (Switzerland) (?)

Procurement Schedule for the GLAST SSD

Tray Production is embedded in the GLAST LAT Schedule



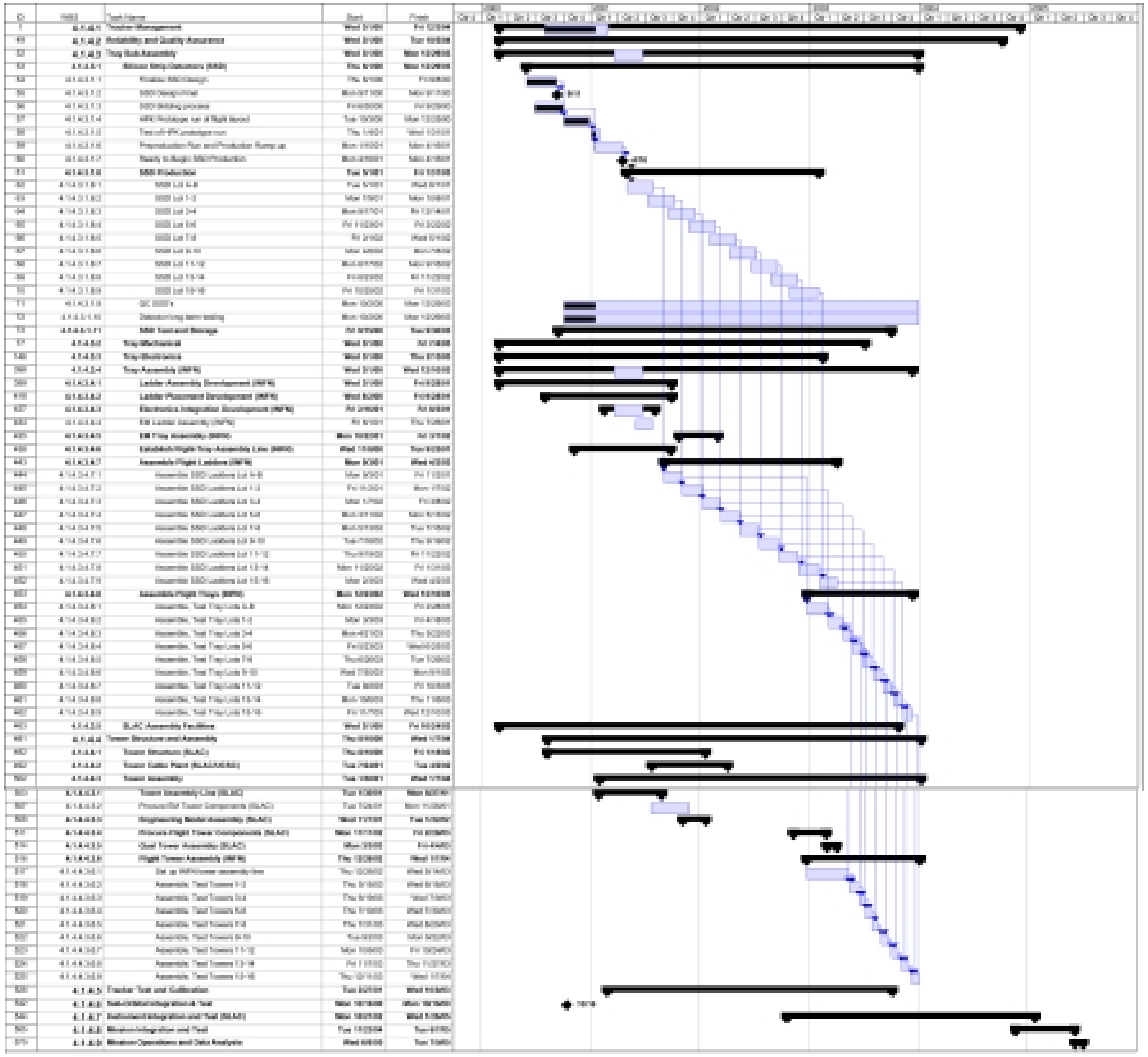
Testing is a large part of the SSD / tray manufacturing process

Procurement Schedule for the GLAST SSD

Procurement of SSD is part of the GLAST tray construction

2001: 500 SSD/month

2002: 1000 SSD/month



Testing/QA for the GLAST SSD

Acceptance QC: flight sensors

- Order high quality SSD → testing of detectors is done by vendor:
  I-V, C-V, bad Channels, Process Parameters. NO single channel current!
- Measurement of parameters crucial for assembly by GLAST assembly institution:
  i-V (and possibly of dimensions)

Process Control: test structures

- Thorough test on test structures, one out of every lot (48) by Hiroshima U. & INFN:
  Measure all detector parameters specified in specifications
- Test wire bonding on test structures

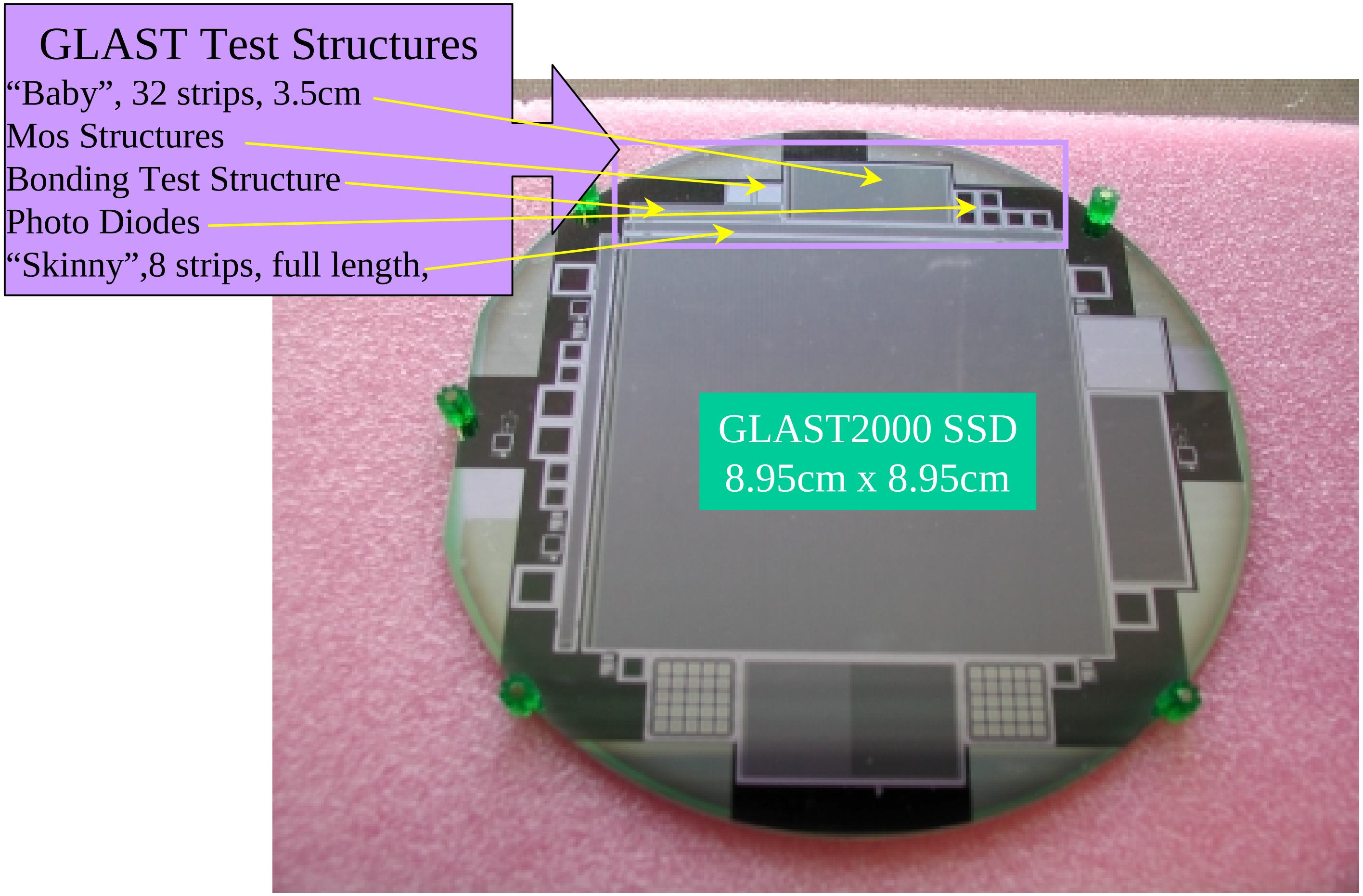
Assembly QA: flight sensors / ladders

- Testing after bonding and encapsulation by GLAST assembly institution:
  "Vital" parameters (I-V of ladders and coupling caps on every strip)
- Test before tray assembly:
  i-V on ladders

This program is based on our experience with the >500 HPK SSD in the Beam Test Engineering Module (BTEM, SLAC-8471).

6” wafer of the GLAST SSD

**Each wafer has a GLAST2000 SSD and a GLAST cut-off.
We are now establishing the correlation between
SSD and test structure performance.**



Test Structures on the GLAST SSD Wafer