ACD Phototube Breakage – solutions and paths

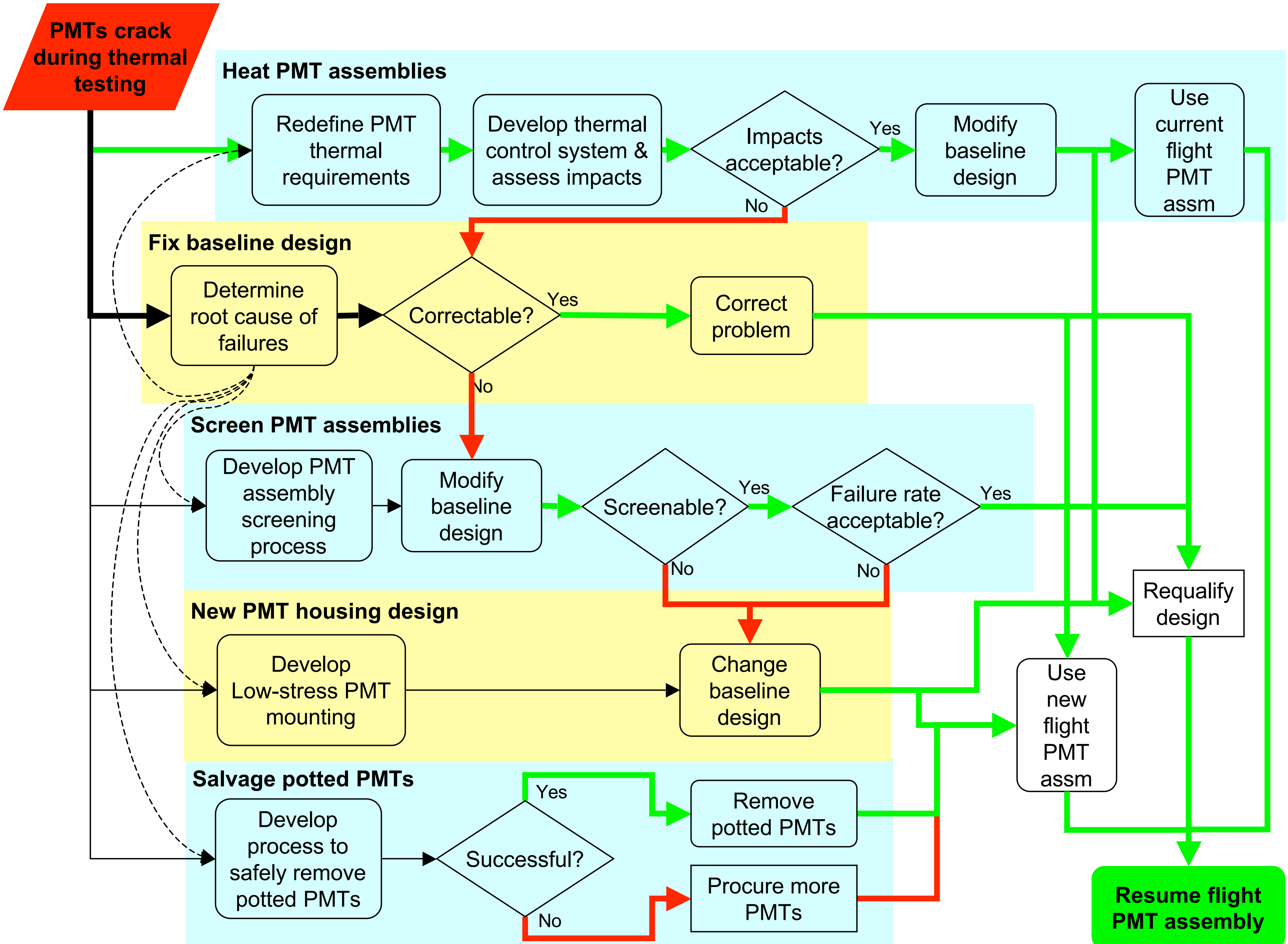
Outline:

- Basic choice
- Top level solution choice flow.
- Top level solution choice flow.
- Top level solution paths
- Individual solutions - basic description and flow
- Solutions moved to backburner, having early problems or not being actively pursued
- Selection criteria

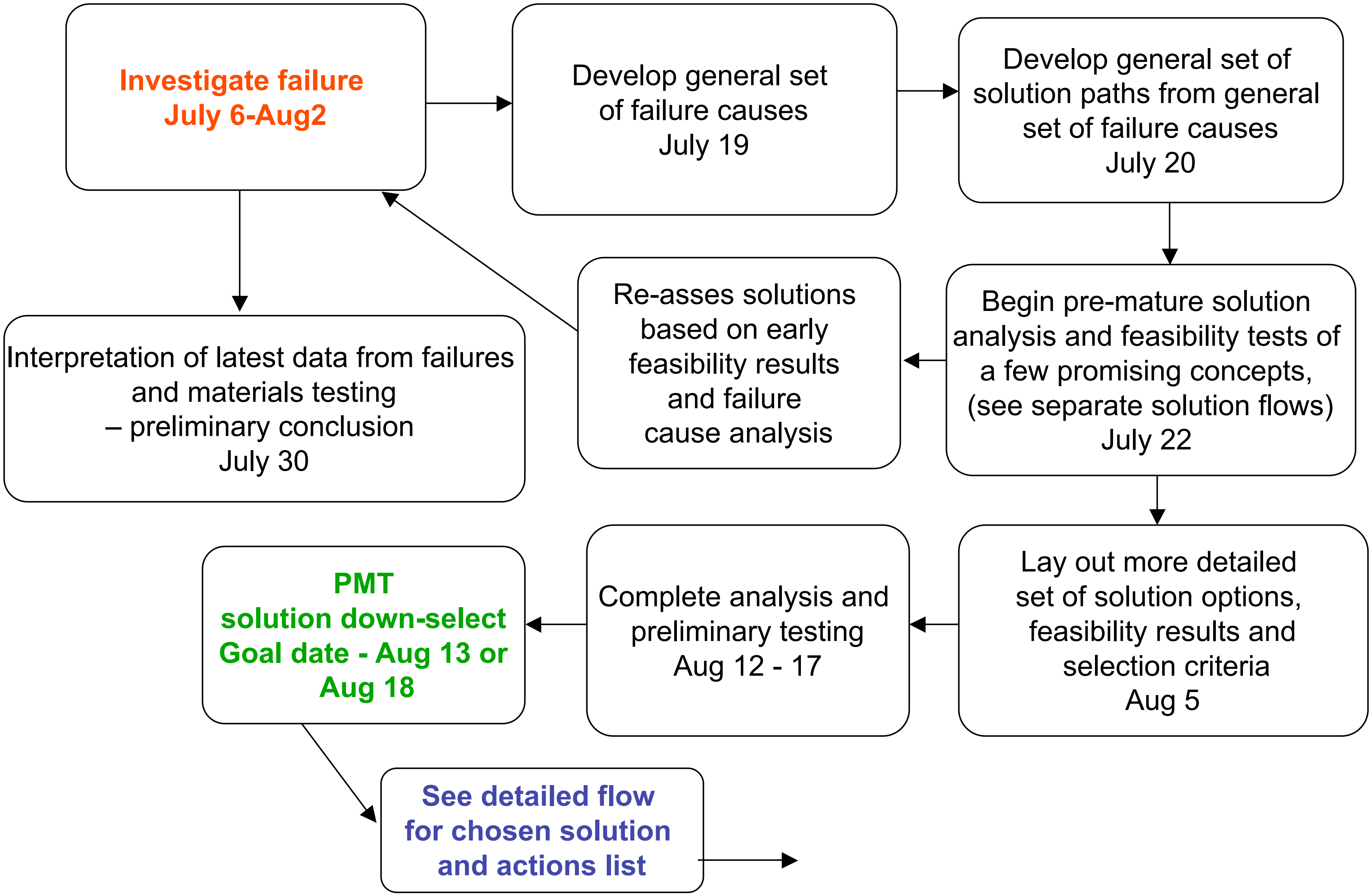
ACD Phototube Breakage – Choosing a solution

Approach:

- Basic listing of solution options done. Now lay out the options in sufficient detail to understand the basic issues.
- Lay out basic solution decision criteria.
- Distinguish two cases and the possibility of combine solution
    - What we do with the 100 tubes already potted
    - What we do with the 140 bare tubes
- Establish top level flow and individual flows for each path with dates
- Pursuit of options with most critical criteria related activates given priority. During pursuit of solutions look for critical missing information or “show stoppers”
- Options that begin to look very hard early on could be put on back burner. This allows eliminate options as quickly as possible as initial prime candidates at least by completing the most critical actions.


PMTs crack during thermal testing
Heat PMT assemblies
Redefine PMT thermal requirements
Develop thermal control system & assess impacts
Impacts acceptable?
Yes
No
Modify baseline design
Use current flight PMT assm
Fix baseline design
Determine root cause of failures
Correctable?
Yes
No
Correct problem
Screen PMT assemblies
Develop PMT assembly screening process
Modify baseline design
Screenable?
Yes
No
Failure rate acceptable?
Yes
No
Requalify design
New PMT housing design
Develop Low-stress PMT mounting
Change baseline design
Use new flight PMT assm
Salvage potted PMTs
Develop process to safely remove potted PMTs
Successful?
Yes
No
Remove potted PMTs
Procure more PMTs
Resume flight PMT assembly

PMT Top Level Solution Path flow



PMT Solution Paths

Possible top level Solution Paths

- Modified Potting Solution – *understand the new variables and stresses in the potting materials*
  - –RTV or more likely an alternate
  - –Must understand exactly how the latest PMTs failed
  - –Slit-potted design. May even be able to do this to already potted PMTs
  - –Others also require removal methods for already potted PMTs

- Thermal control solution – *don't let the PMTs see the stress of lower temperatures.*
  - –Heaters to -5 or 0C, Must determine via test what is warm enough
  - –Allows us to fly PMTs that have already been potted

- Mechanical solution – *get out of the potting business since it looks like the material properties vary too much for these flawed tubes.*
  - –Partial CTE compensation design. Uses modified existing housings with inserts, does still add some stress but mostly compressive
  - –Quasi kinematic mounts. Various forms. Simple versions may be able to use existing housings with inserts
  - –Bonding release designs. Releases bonding on one side, grooved housings keep PMT from slipping

- Determining Yield in current design – *see if there is a screening test that stresses the PMTs in a way that identifies almost all the PMTs that will fail without consuming lifetime of the PMTs that pass or making them more likely to fail.*
  - –Probably have to screen and partial life test large number of PMTs (which may be tough to then use as flight) to show it could work.

- Any combination of above with combined with some or all new PMTs *without so many glass flaws*
  - –First 6 units with modified Hamamatsu process are not flawless but are all dramatically better than any of the original tubes we have*Note : Some solutions also require removal methods for already potted PMTs*

Proposed Selection Criteria

- STRESS AND STRAIN - Reliably lowers stress to under 1000 psi for tensile stresses with a goal of < 500 psi. (Tensile limit from our test data, literature and gives margin from inside score Weibull test results.) Keeps compressive stresses to TBD (< 2500-5000 psi) compressive stresses. Show by analysis and strain test if possible. Higher compressive stresses must be shown to truly be compressive with no variables that could cause associated tensile stresses

- FEASIBILITY - Passes prototype feasibility tests (assemble-able, controllable, seems repeatable). Friendly to being assembled in large numbers.

- MINIMUM PROTOTYPE TESTS - Passes prototype thermal test in a rail, light tight and vibration test (could we down-select without vib test to save time?).

- LOW VARIABLY RISK – low number of variables or that could effect stresses or ACD performance. Low sensitivity effect on stress on variables we cant control.

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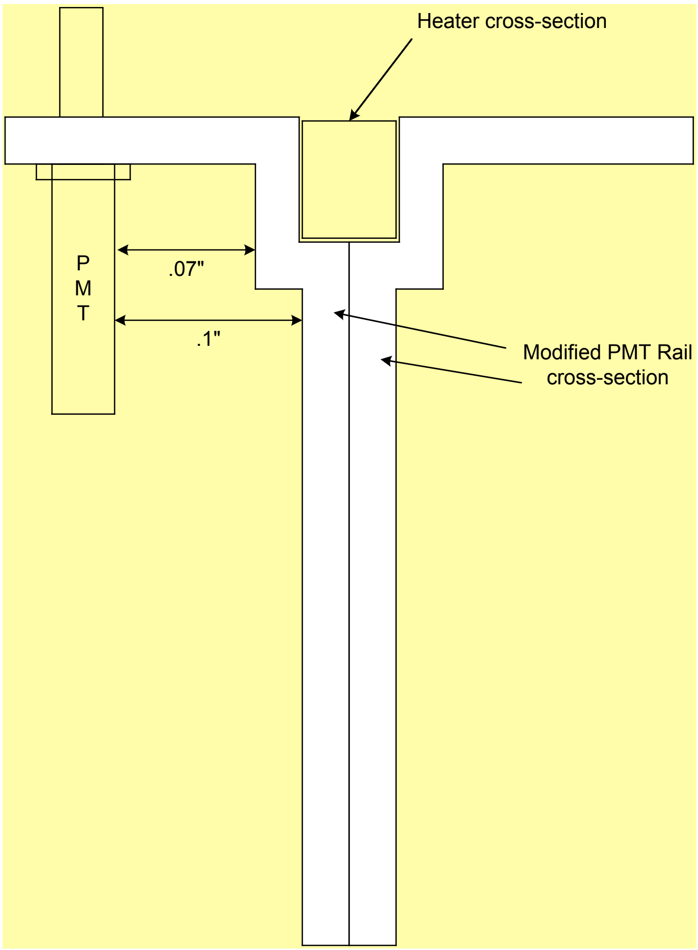
- SCHEDULE (& cost). Subjective, could also be used as tie breaker, some solutions could be eliminated sooner solely on this basis.

ACD Phototube Breakage –Heater Option

Concept:

- Heat phototubes to prevent breaking
- Mount heaters to rails that hold tubes
- Use thermostats to keep temperatures above set point where there is a risk of PMT failure



Pros:

- Can use existing potted tubes
- Might heat some chassis, then develop lower-stress mounting for other tubes.

Cons:

- New wiring and electrical control for heaters needed (LAT or spacecraft changes required)
- Masking, but not eliminating, the fundamental cause of the breakage
- EMI risk from switching high current near front-end electronics (has been seen on other missions)
- Amount of power available is not certain, Will require large amount of power, setting temp point with enough margin.
- Greater thermal heat load being dumped to the grid
- May require redesign to Electronic Chassis and/or PMT rails

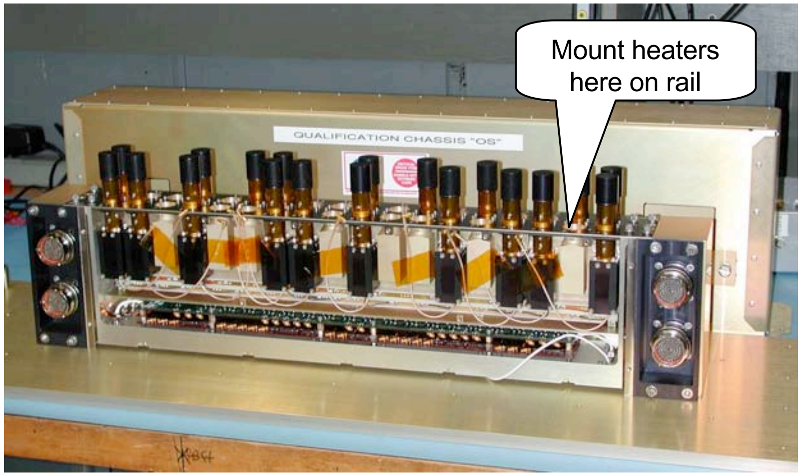
ACD Phototube Breakage – Heater Option

Status:

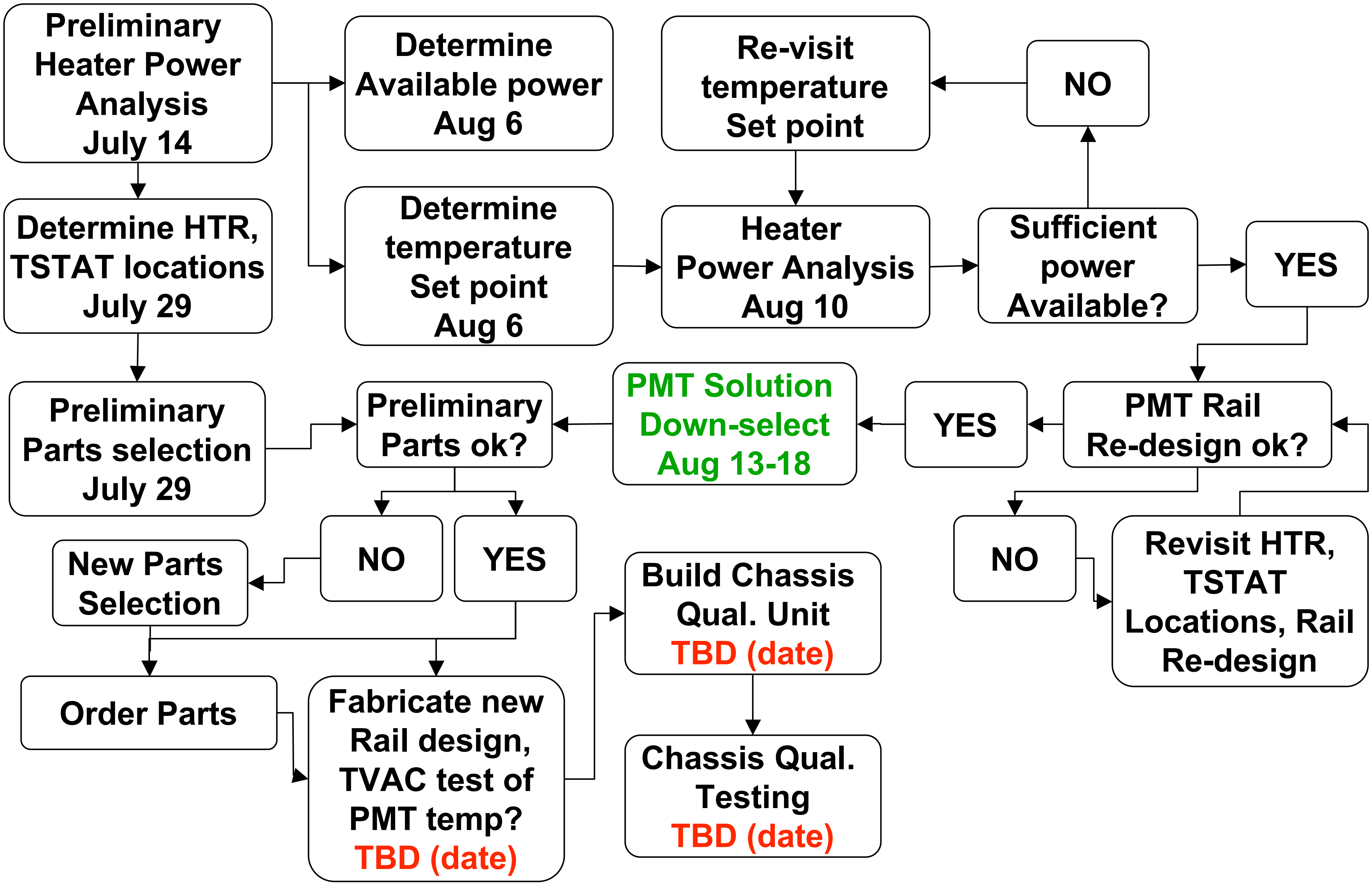
- Power estimates made (~150w at -5C) in a survival worst case condition (+Z facing the sun)
- Preliminary Heater selection complete (Minco Kapton Heaters)
- Preliminary Thermostat selection complete (Klixon 5BT)
- Preliminary controller design complete (1 controller per Chassis)

Actions:

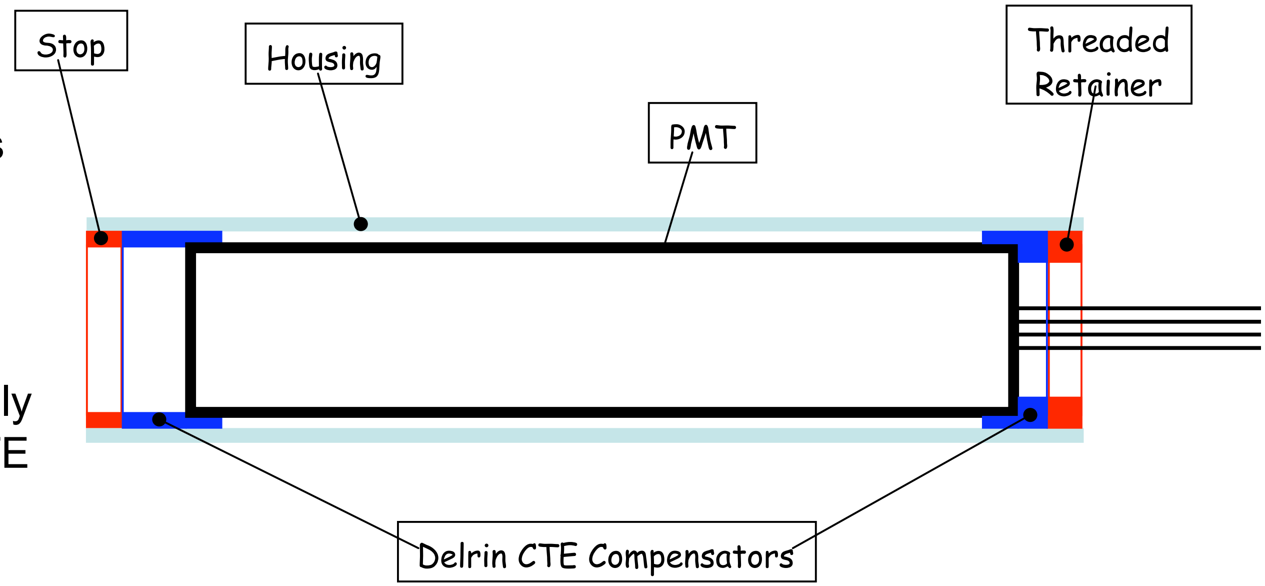
- Determine safe temperature for tubes (analysts)
- Determine source of heater power necessary for this system (Project)
- Determine locations for wiring, control circuit, and heater configuration (Unger)
- Test for possible EMI with heater power switching near electronics, if power is needed during operational mode (Odom/Sheppard)
- More detailed heater power analysis (Peters)



Alternate Design – PMT Heater Design



Mechanical mount - Partial CTE Compensation Option



Concept:

•No potting, hold the tubes at the ends with inserts
•Small clearances and some CTE compensation limit radial stress
•Longitudinal stress partially compensated by insert CTE

Pros:

- Can use existing housing design
- No RTV or other potting material and related material properties variables and testing.
- PMTs removable if there is a problem
- Relatively easy assembly

Cons:

- CTE difference is not fully compensated
- Preload required on PMT. Should be in compression but tube dimension errors will likely cause tension
- Force exerted will increase at cold extremes approximately 4X initial preload to 1500 psi
- Custom machined parts to match PMTs

Mechanical mount - Partial CTE Compensation Option

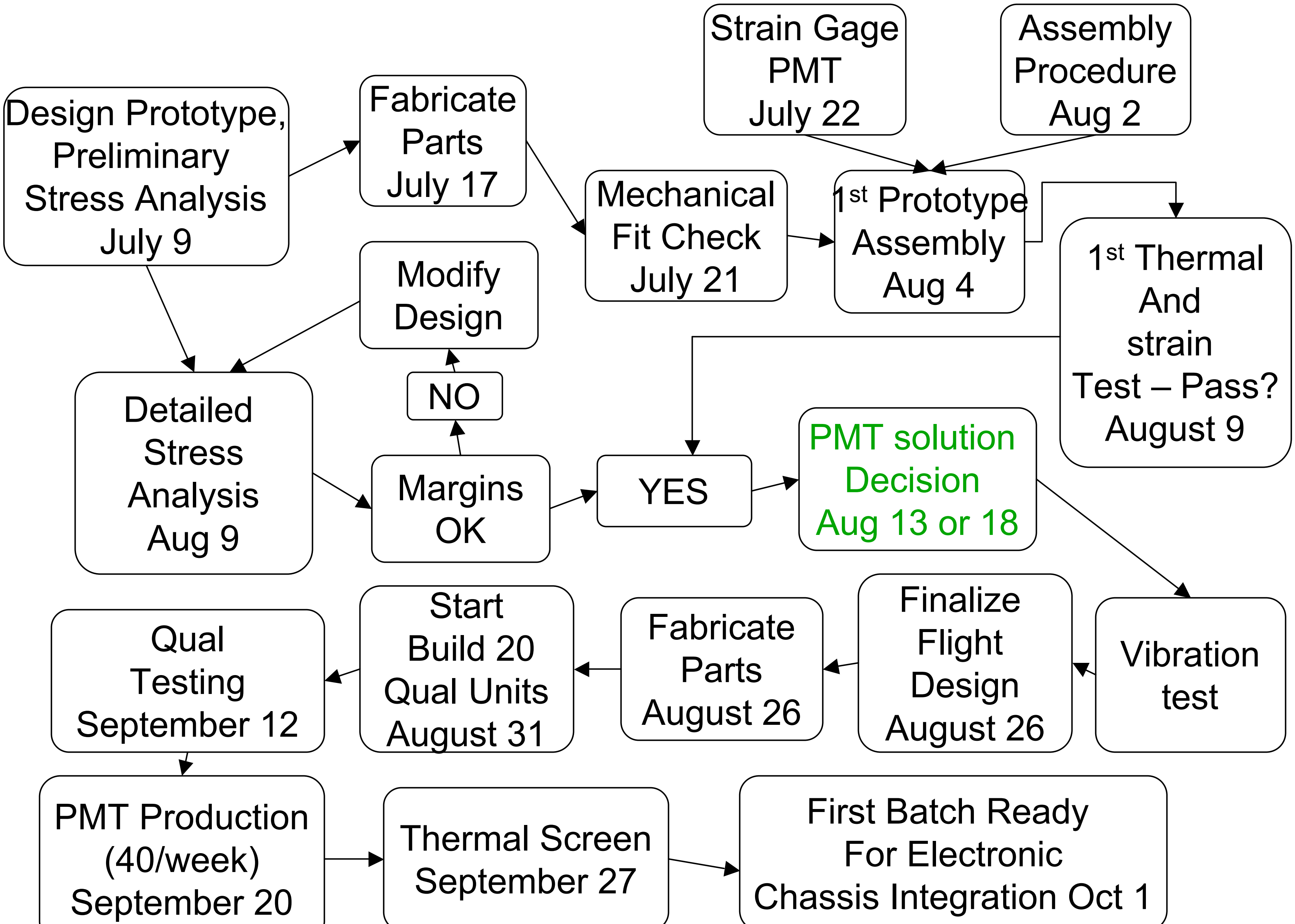
Status:

- Rapidly prototyped last week
- Room temperature prototype torque testing completed

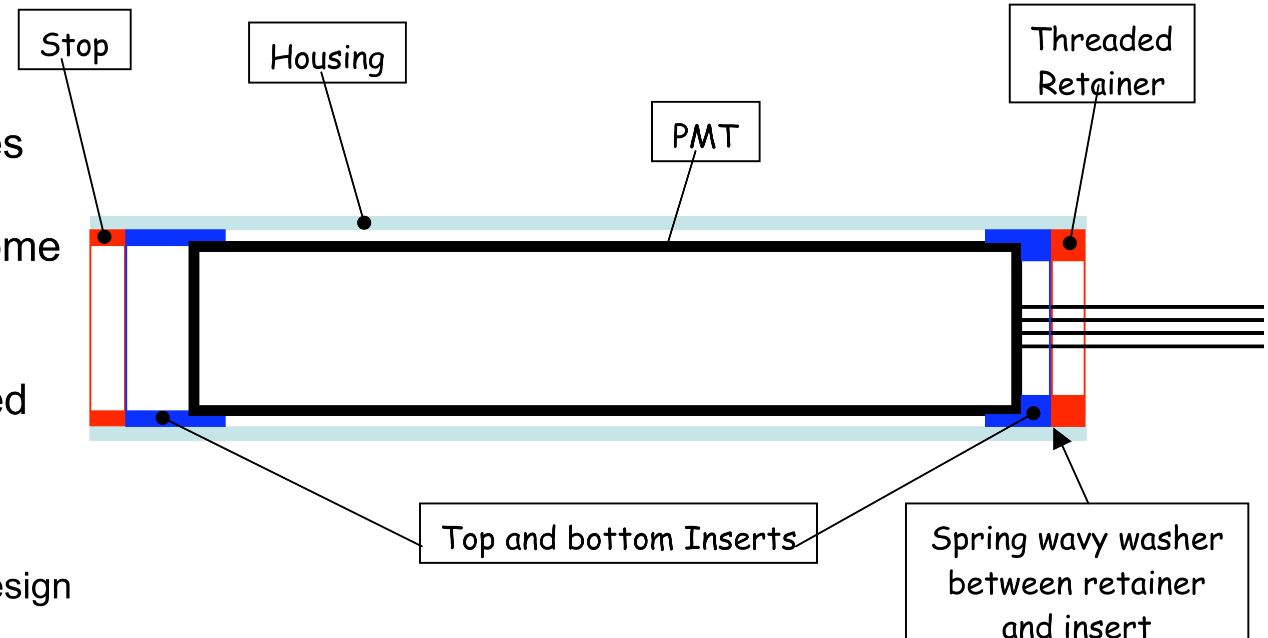
Actions:

- Thermal test 1 prototype
- Finish stress analysis
- Repeat test with more PMTs?

Mechanical mount - Partial CTE Compensation Option



Mechanical mount - Partial Spring Compensation Option



Concept:

- No potting, hold the tubes at the ends with inserts
- Small clearances and some CTE compensation limit radial stress
- Longitudinal stress limited by spring

Pros:

- Can use existing housing design
- No RTV or other potting material and related material properties variables and testing.
- PMTs removable if there is a problem
- Relatively easy assembly

Cons:

- Spring constant will vary, spring throw is not much.
- Preload required on PMT. Limited by spring so less of a concern. Should be in compression but tube dimension errors will likely cause tension.
- Could tube move slightly in vibration, does it matter as long as clear fiber spring has throw left and leads are ok?
- Custom machined parts to match PMTs

Mechanical mount - Partial Spring Compensation Option

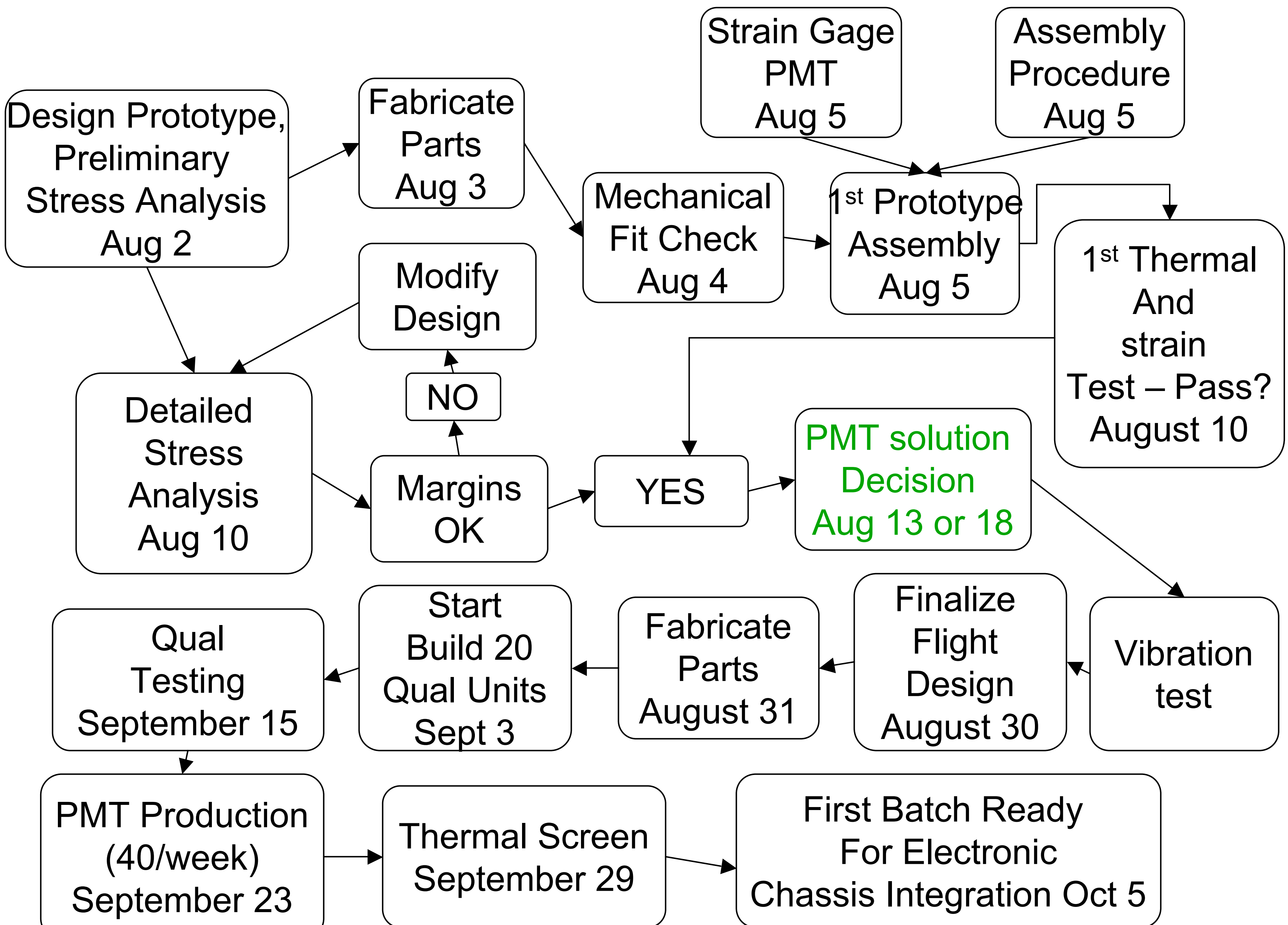
Status:

- Rapid prototyped this week
- Room temperature prototype load testing completed

Actions:

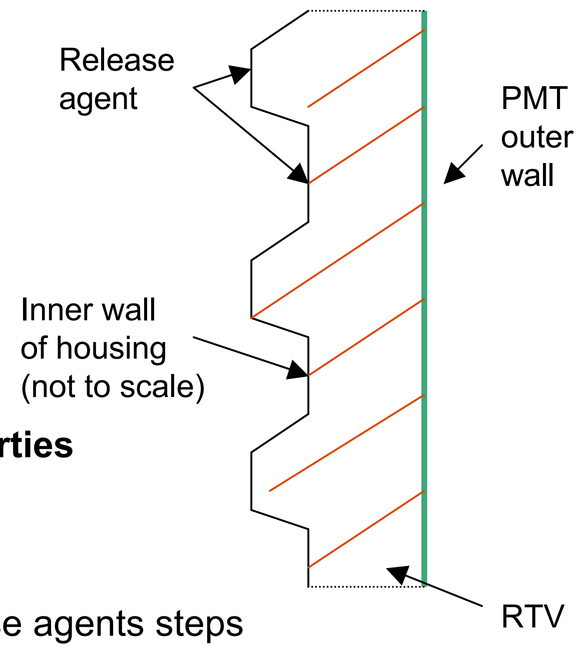
- Thermal test 1 prototype
- Finish stress analysis
- Repeat test with more PMTs?

Mechanical mount - Partial Spring Compensation Option



ACD Phototube Breakage – De-bonded PMT Housing Design

- **Concept: Add a release agent to the inner wall of the housing so the RTV-566 will not adhere, thus reducing stress on the glass tubes**



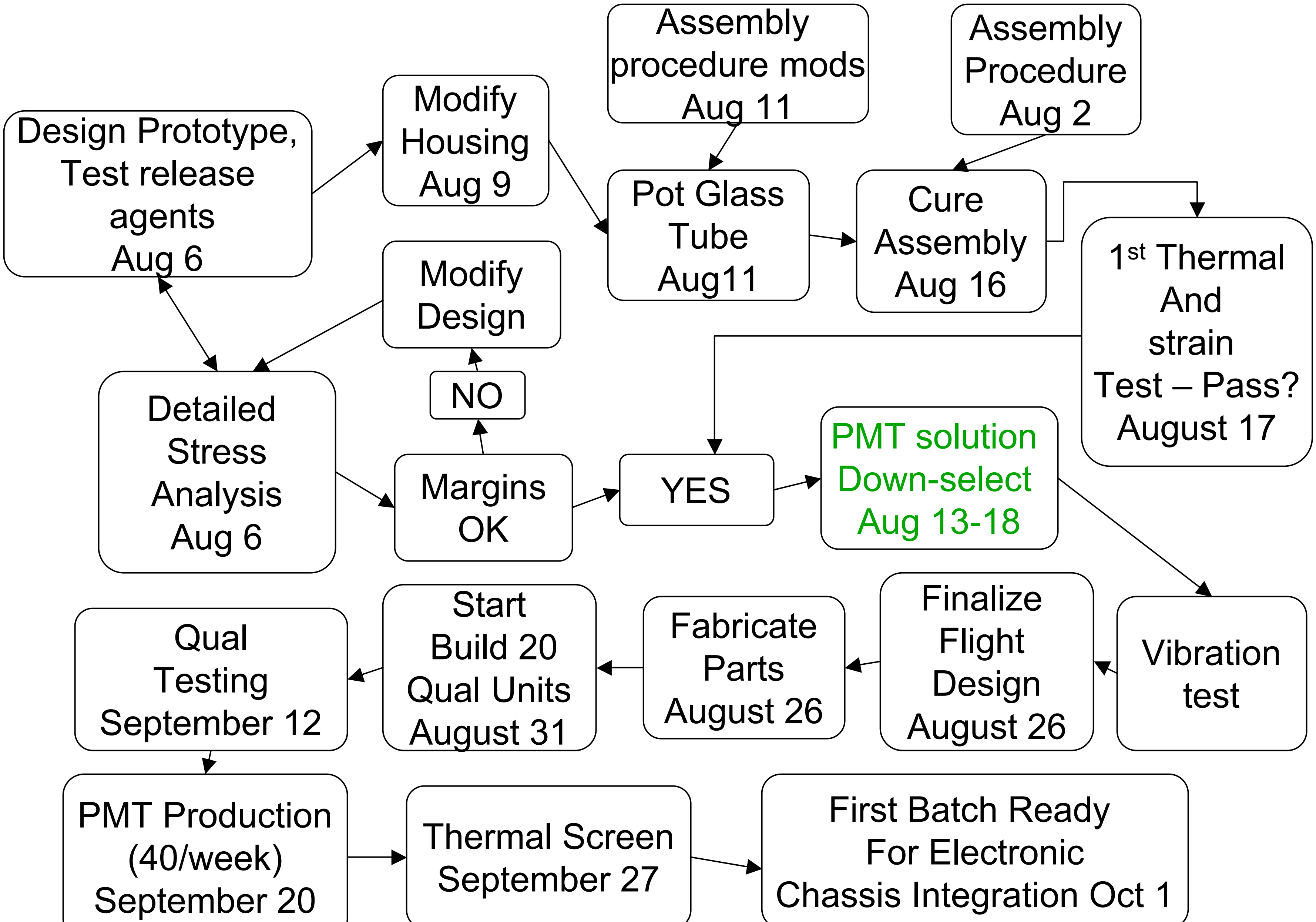
- **De-bonding agent applied to Al housing**
- **Grooves, threads or some other method added to prevent longitudinal glass tube motion**
- **Glass tube potted as before**
- **RTV-566 is allowed to expand and contract with glass**
- **May try to select RTV batches that tend towards better properties**

- **Pros:**
  - Used with glass tubes not already potted,
  - uses existing design and process adding grooves and release agents steps
  - Stress on glass tube is reduced because RTV is not adhering to the Al housing, therefore the RTV can expand and contract freely with temperature
- **Cons:**
  - Must find and test adequate de-bonding agent very soon
  - Must ensure that RTV does not adhere to Al housing during potting; workmanship issue
  - Not applicable for existing potted PMT housings

ACD Phototube Breakage – De-bonded PMT Housing Design

- **Status:**
  - Analysis ongoing
    - Modify FEM to release RTV elements from housing
    - Constrain RTV in housing to model threads
    - Perform thermal analysis using ΔT = -60°C (+20° to -40°C)
- **Actions:**
  - Design method to hold glass tubes and RTV vertically in housing, what kind of grooves or threading the inside of the Al housing
  - Pot a prototype and allow it to cure
  - Thermally test the prototype

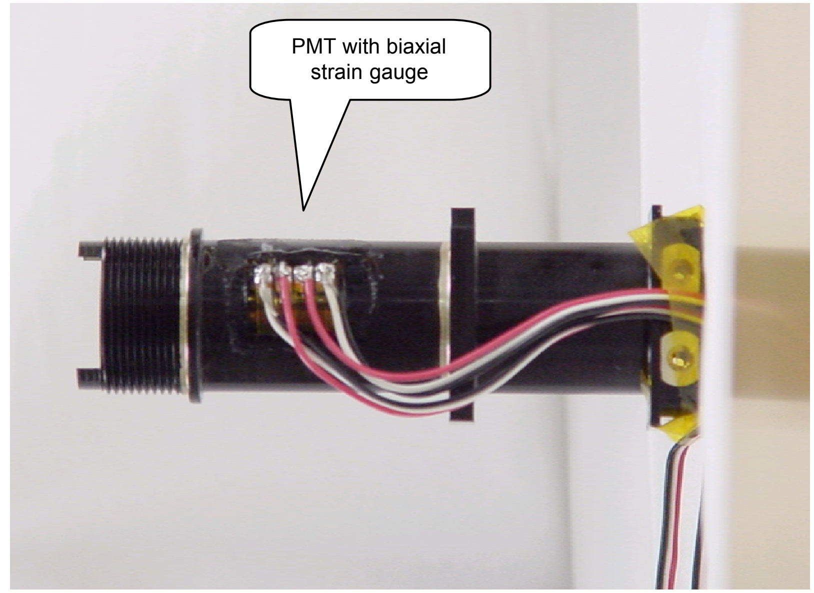
Alternate Design – De-bonded PMT Housing Design



ACD Phototube Breakage – Screening of Potted Phototubes

Concept: Determine the variations in stress on the potted phototubes

- **Mount strain gauge to the aluminum housing.**
- **Thermal cycle the phototubes from 0°C to +40°C and evaluate the thermal stresses.**
- **Thermal cycle the lower stressed phototubes to the acceptance temperatures (-30°C to +40°C)**



Pros:

- Determine what is driving the phototube failures (flaws population or variations in stress).
- Screen the existing potted phototubes by determining the variations in stress.
- Potted phototubes that showed lower stresses can be used as is.
- Low cost (Save in materials and labor cost to rework the lower stress phototubes)

Cons:

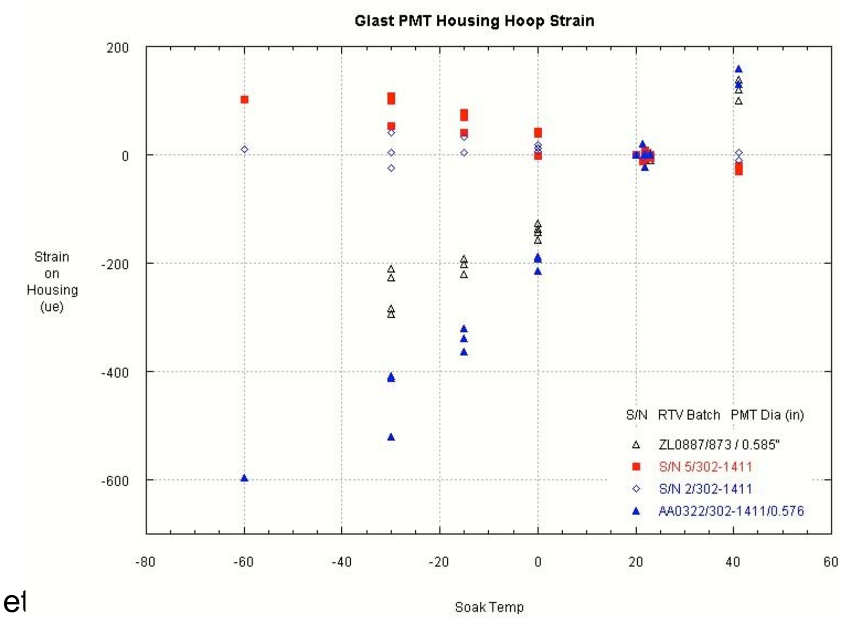
- Possible brakeage of phototubes in the acceptance thermal cycle.
- Adhesive used to bond the gauges is a cyanoacrylate (high outgasser)
- Rework potted phototubes that show higher stresses.

•Status:

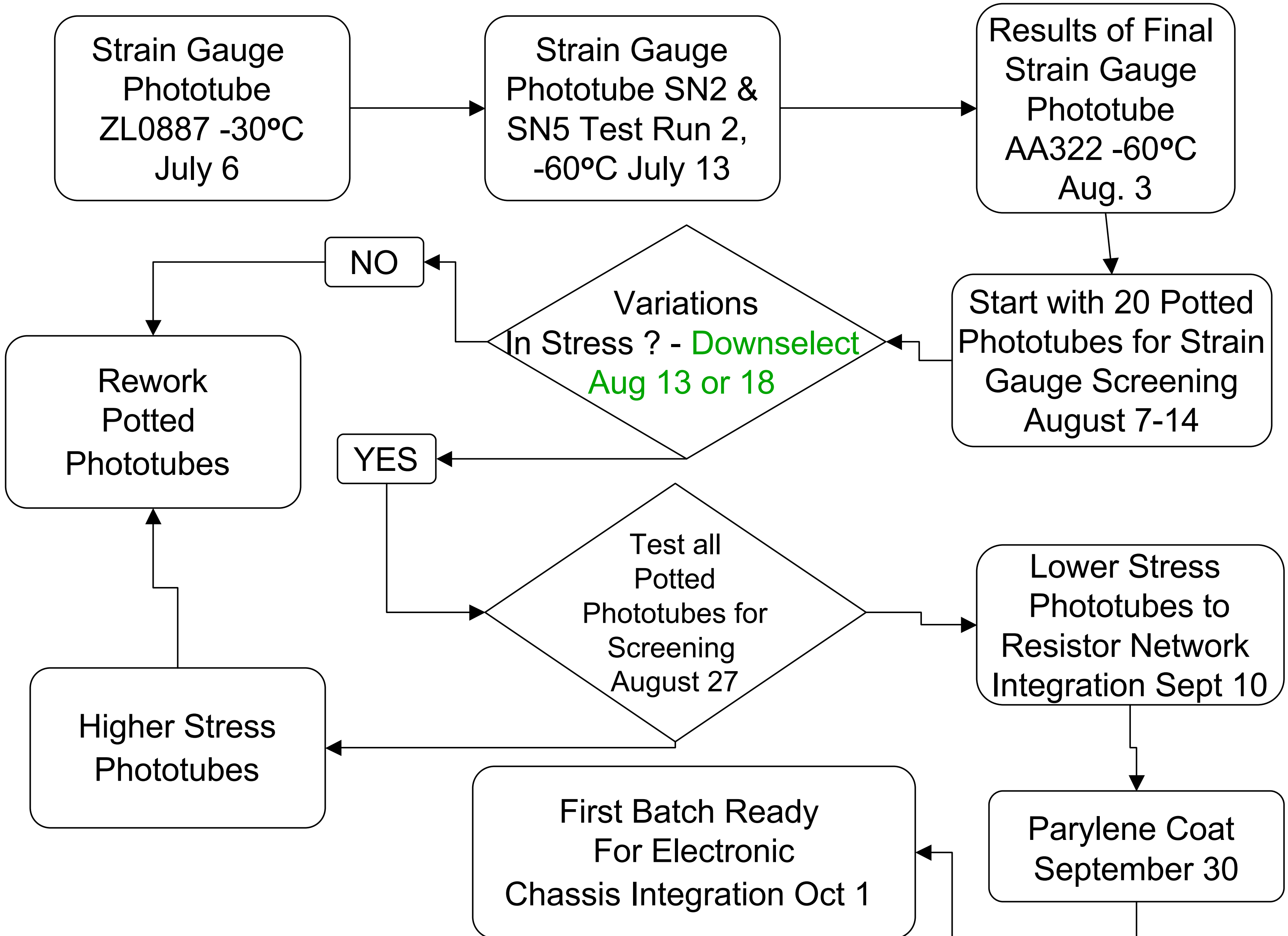
- Tested four (4) potted phototubes to prove concept.

•Actions:

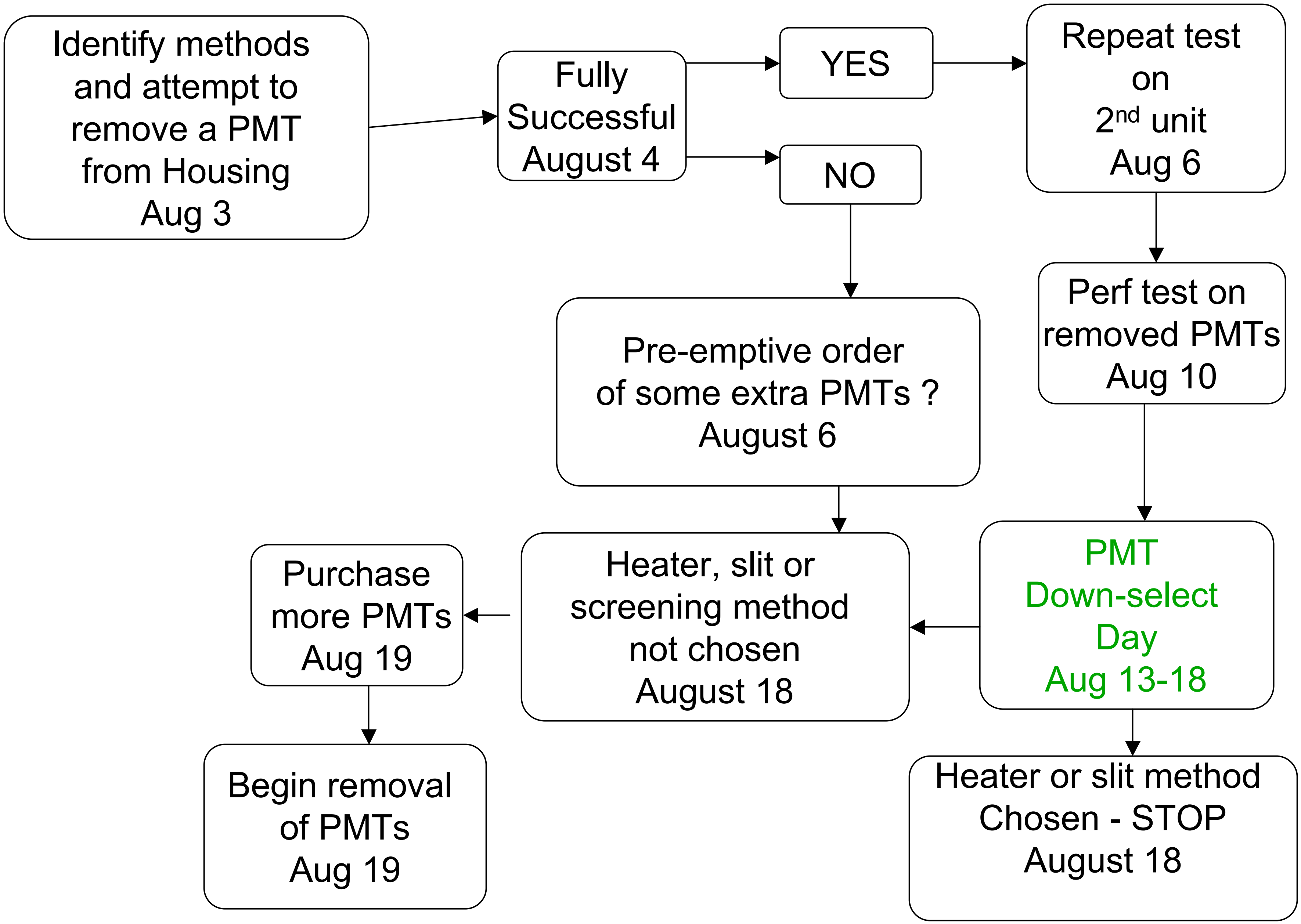
- Verify the ability to remove the cyanoacrylate adhesive from the housing for the bonding of the strain gauge.
- Order additional single strain gauges from the same lot number.



Screening of Potted Phototubes



PMT Recovery or Purchase Issue



<u>Some options are not being currently being actively pursued.</u>

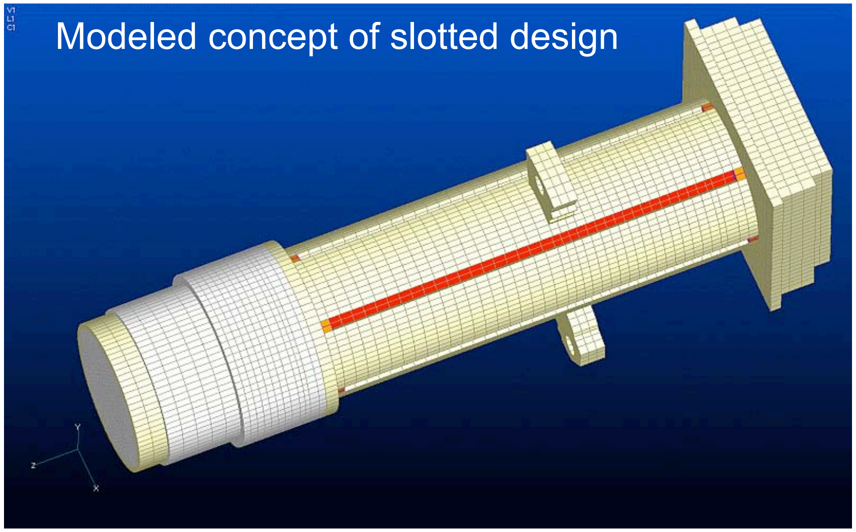
- **One was dropped off the actively pursued list due to poor early analysis or test results – Slit method**

- **Some were deemed early on to be too complicated for the potential return, or too long to fully implement and test etc.. Could be reconsidered**

ACD Phototube Breakage – Slotted PMT Housing Design

- **Concept: Cut slots into the sides of the potted PMTs to attempt to reduce the stress on the glass; Six slots were added**

- **Machine mounting flange down to tabs**
- **Machine slots the entire length of the housing**



- **Pros:**
  - Can use existing potted tubes
  - Machining has been shown to be possible
- **Cons:**
  - Creates stress concentrations on the glass under the mounting tabs that is significantly higher than previously encountered
  - Would require some additional means to reduce the stress

ACD Phototube Breakage – Slotted PMT Housing Design PMT

- **Status:**
  - Analysis has been performed
    - Rail section added to be more realistic
    - Bulk temperature change applied, ΔT = -60°C (+20° to -40°C)
    - Results show unacceptably high stress concentrations on the PMT glass tubes under and between the mounting tabs
    - Local stress concentrations are about three times higher than without slots
    - Stress concentrations are caused by the additional stiffness added by the rail to which the housing is mounted; the rail does not allow the tabbed sides to contract the same as the non-tabbed sides
  - One PMT housing was machined in a similar fashion to try to remove the housing
    - A 1/8” wide slot was machined into the housing
    - Nothing more was done to the unit
- **Actions:**
  - None pending at this time
  - Stress results from analysis would seem to indicate this is not a plausible solution
  - Analyze a three-slot solution

Other options not being actively pursued – could be reconsidered

- Kinematic Mount – 3 point flex mount. Very low stress but complicated to design and implement. High risk of requireing new housings and more mass which could have ripple effects on rail

- Thermal yield screening. Hard to select test that screens out bad RTV or week PMTs that also does not consume or partially damge PMTs that pass. Could be done but a large number (>30) tubes would have to be put through the proposed screening then put through partial life test to show screening worked

- CTE compensation mechanical design – Uses inserts to hold PMTs, no RTV. Inserts compensate for some but not all of CTE difference in long direction, radial clearances aid CTE compensation. Rapidly designed and machined early version to get it into testing. Early tests show we can not hold preload due apparently to creep issues in some of the CTE compensation inserts

- New potting material – same design – This is essentially what we did the first time. Given the radical changes in RTV materials between batches and between cures within batch, we see this s a larger development and test effort