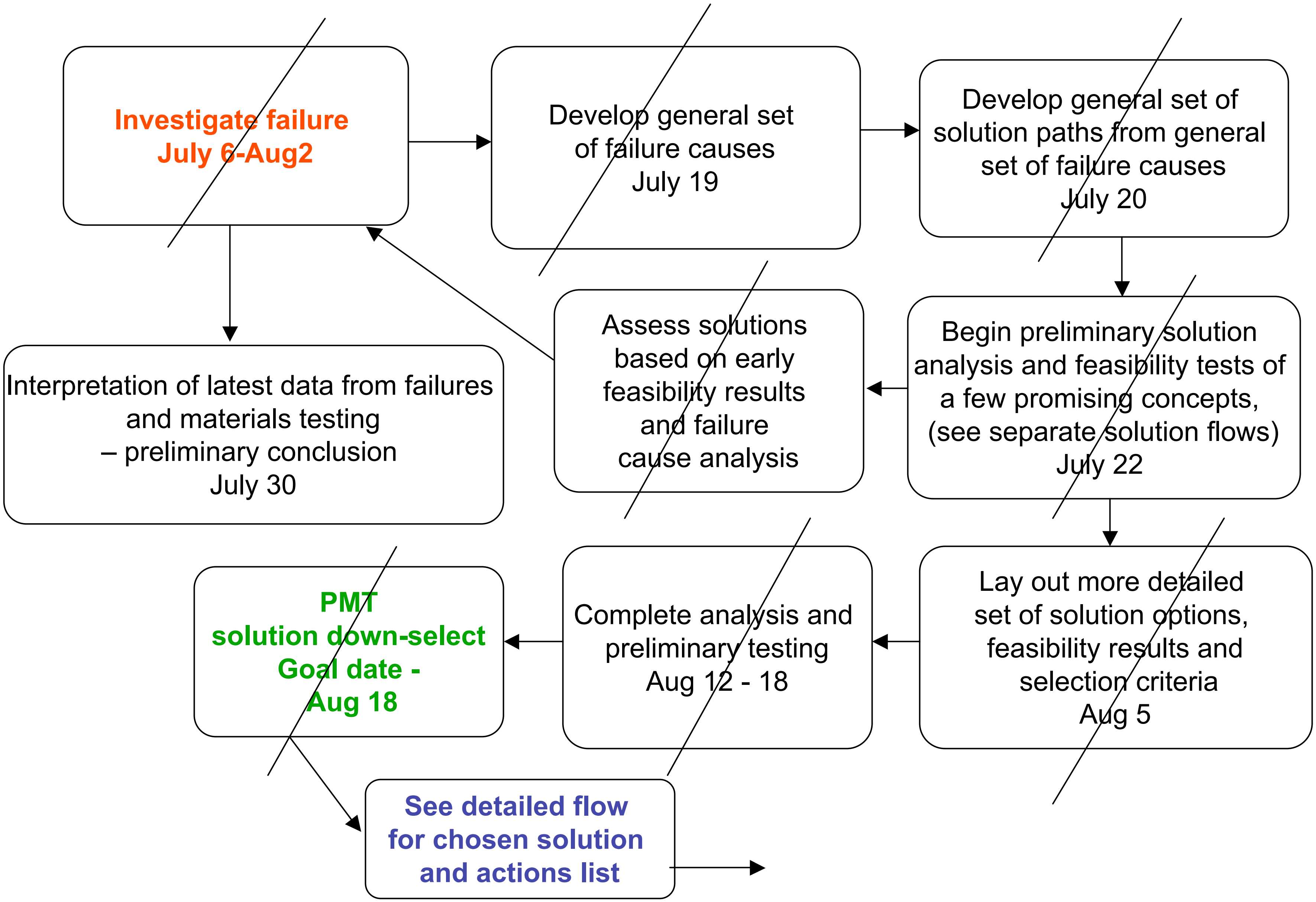
ACD Phototube Breakage – Choosing a solution

Approach:

- Basic listing of solution options done. Layed out the options in sufficient detail to understand the basic issues.
- Established 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
- Established and executed top level flow and individual flows for each path with dates
- Options that begin to look very hard early were put on back burner. This allowed elimination options as quickly as possible as initial prime candidates at least by completing the most critical actions.

PMT Top Level Solution Path flow



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 under 6000 psi** (goal < 3000psi). 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

- 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.

‘

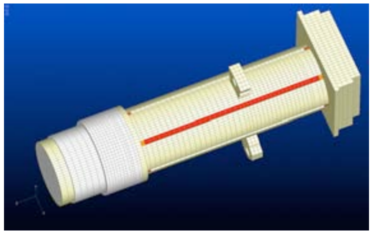
- SCHEDULE (& cost). Subjective, could also be used as tie breaker, some solutions could be eliminated sooner solely on this basis.

Options no longer being actively pursued –

Some were deemed early on to be too complicated for the potential return, or too long to fully implement and test etc.. Some did not look good in early analyses

- Slit design – looked promising in first cut analysis and machining tests but later analysis showed it would not do the job
- 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. Includes finding ways to control RTV

‘



ACD Phototube Breakage –Heater Option

Concept:

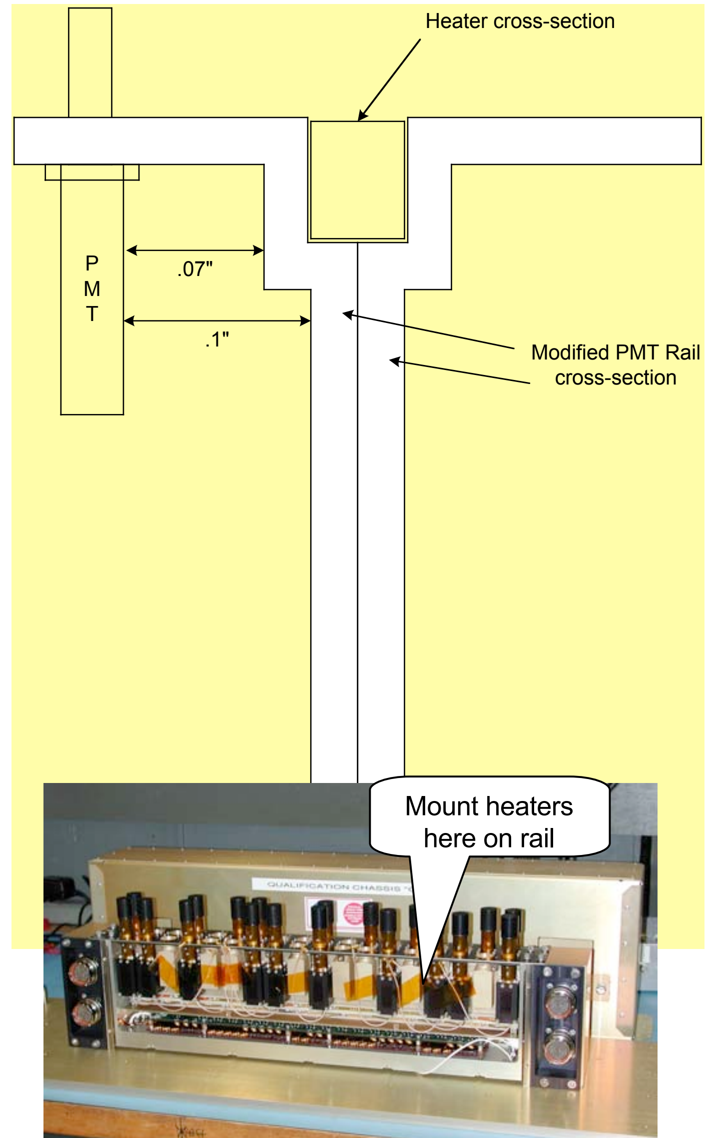
- Heat phototubes to prevent breaking
- Mount heaters to rails that hold tubes
- Use thermostats to keep temperatures above set point where there is a risk of PMT failure

Pros:

- Can use existing potted tubes
- Could heat some chassis and use lower-stress mounting for other tubes.

Cons:

- New wiring and electrical control for heaters needed (LAT and/or spacecraft changes required)
- EMI risk from switching high current near front-end electronics (has been seen on other missions) if heaters are needed during science operations
- Erodes LAT survival and possibly operational power margins
- Greater thermal heat load being dumped to the grid if heaters required during science operations
- May require redesign to Electronic Chassis and/or PMT rails

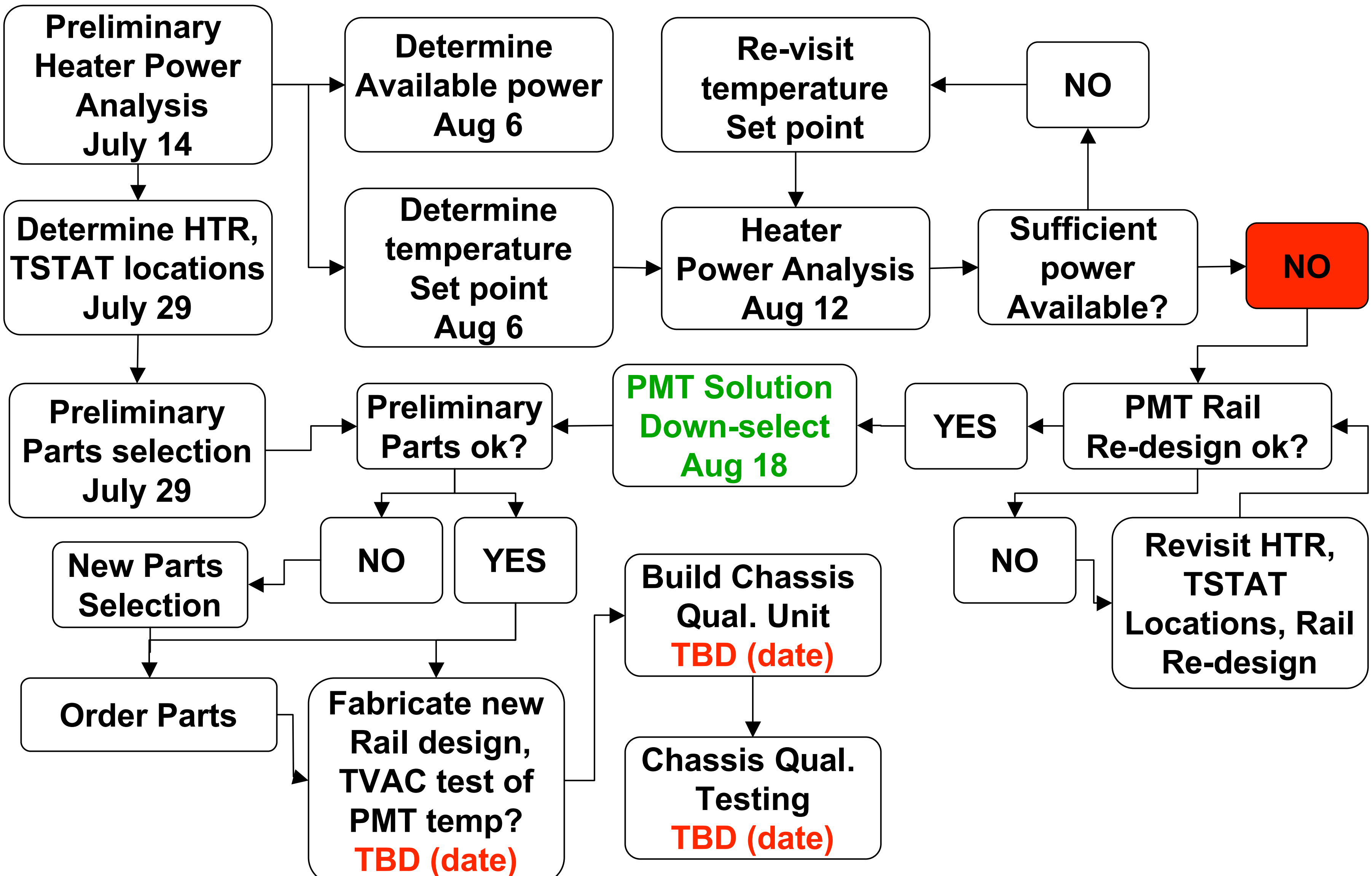


ACD Phototube Breakage – Heater Option

Status:

- Baseline survival feed from spacecraft limits available power to ~75W OAP with MAR 30% duty cycle requirement
  - Assumes increase of LAT allocation on that feed from 220W to 285W
  - Would require modifications to the LAT Heater Control Box
    - Update and release of drawings
    - Re-layout of the HCB board
    - Retest of HCB
    - Routing ACD heater cables on BEA looks doable
- If we hold this concept to our minimum selection criteria, 15C is required to keep the worst RTV batches under 1000 psi tension
  - This puts heater switching into the operational temperature range
    - Would need a set point of 0C to prevent switching during science operations
  - We are taking a new look at the 15C for 1000 psi calculation looking for relief to allow more heated possibilities
- 100W to 140W just to heat already potted PMTs to 15C, double to heat all rails
  - Hot operational case limits prevents use of thermal isolation of PMTs
- Modifications to survival feed from spacecraft not explored because of observatory safemode energy reserve concerns
- Heating a few rails (could be less than needed to accommodate all already potted PMTs) could be considered
- Heating to -15C is the only temperature that the current spacecraft feed can support
  - Could be used in combination with some type of design change and rework (for example another potting option that is not good enough for -40 or -30C but good enough for -15C)

Alternate Design – PMT Heater Design



Backup - Heater solution power

Survival Orbit Scenario:	+Z axis sun pointed, all rails heated			
Temperature Set Point °C	**-15**	**-5**	**0**	**15**
+X Chassis htr power	22	35	50	-
+Y Chassis htr power	14	27	43	-
-X Chassis htr power	19	31	47	-
-Y Chassis htr power	24	36	51	-
Total hp (Watts)	**79**	**128**	**191**	**318**

Survival Orbit Scenario:	+Z axis sun pointed, +X,-Y rails heated			
Temperature Set Point °C	**-15**	**-5**	**0**	**15**
+X Chassis htr power	26	46	55	85
+Y Chassis htr power	0	0	0	0
-X Chassis htr power	0	0	0	0
-Y Chassis htr power	28	47	56	86
Total hp (Watts)	**54**	**92**	**112**	**171**

Survival Orbit Scenario:	+X axis sun pointed, all rails heated			
Temperature Set Point °C	**-15**	**-5**	**0**	**15**
+X Chassis htr power	0	0	8	-
+Y Chassis htr power	20	40	49	-
-X Chassis htr power	19	38	48	-
-Y Chassis htr power	19	39	49	-
Total hp (Watts)	**58**	**117**	**154**	**273**

Survival Orbit Scenario:	+X axis sun pointed, +Y,-X rails heated			
Temperature Set Point °C	**-15**	**-5**	**0**	**15**
+X Chassis htr power	0	0	0	0
+Y Chassis htr power	20	40	50	83
-X Chassis htr power	20	40	50	83
-Y Chassis htr power	0	0	0	0
Total hp (Watts)	**39**	**80**	**99**	**165**

Survival Orbit Scenario:	+X,+Y sun pointed, all rails heated			
Temperature Set Point °C	**-15**	**-5**	**0**	**15**
+X Chassis htr power	0	9	19	-
+Y Chassis htr power	0	6	16	-
-X Chassis htr power	18	37	47	-
-Y Chassis htr power	20	40	49	-
Total hp (Watts)	**39**	**93**	**131**	**252**

Survival Orbit Scenario:	+X,+Y sun pointed, -X,-Y rails heated			
Temperature Set Point °C	**-15**	**-5**	**0**	**15**
+X Chassis htr power	0	0	0	0
+Y Chassis htr power	0	0	0	0
-X Chassis htr power	18	38	49	80
-Y Chassis htr power	20	40	51	82
Total hp (Watts)	**39**	**78**	**100**	**163**

- Based on "old conductance value for PMT rail to base frame
- Newer conductance value reduces power estimates by ~15%

Thermal Design Results

Description	Cold Op. Temp.	Cold Surv. Temp.	Hot Op. Temp.	Hot Op. Temp.	Hot Op. Temp.	Hot Op. Temp.	Operating Temperature Limits	Survival Temperature Limits
Grid Boundary	-10	-20	***20***	***12***	***20***	***12***	-	-
Trackers Boundary	-10	-20	25	25	25	25	-	-
PMT Rail	15	15	36	30	34	28	15 to 35	15 to 45
Heater Power (Watts)	210	268	N/A	N/A	N/A	N/A	N/A	N/A

Old conductance value for PMT Rail to FRAME

- All temperatures in ºC
- Predictions shown are raw predicts and margin does not reflect 5 ºC analytical uncertainty

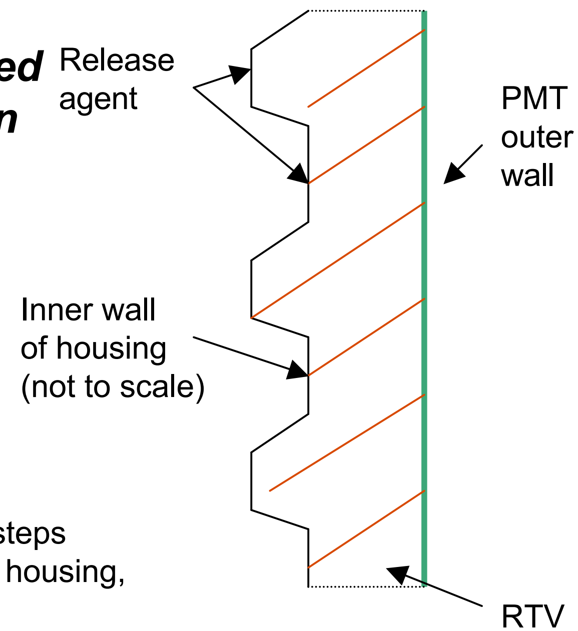
ACD Phototube Breakage –
De-bonded PMT Housing Design
(grooved and strip versions)

- **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**

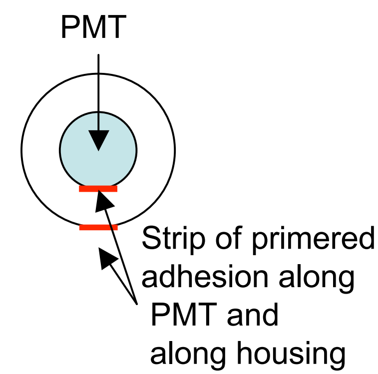
- **De-bonding agent applied to Al housing**
- **Grooves, threads or some other method added to prevent longitudinal glass tube motion**
- **Glass tube potted as before**
- **RTV-566 is allowed to expand and contract with glass**
- **May try to select RTV batches that tend towards better properties**

- **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:**
  - De-bonding agent will be a contamination concern
  - Must ensure that RTV does not adhere to Al housing during potting; workmanship issue, will require strain screening
  - Not applicable for existing potted PMT housings
  - Takes longer to assemble than mechanical solutions
  - Cant remove PMTs easily after assembly
  - Cant directly measure strain in glass on prototypes
  - Strip approach prototyped without release agent because of cross contamination concerns with primer

Grooved version



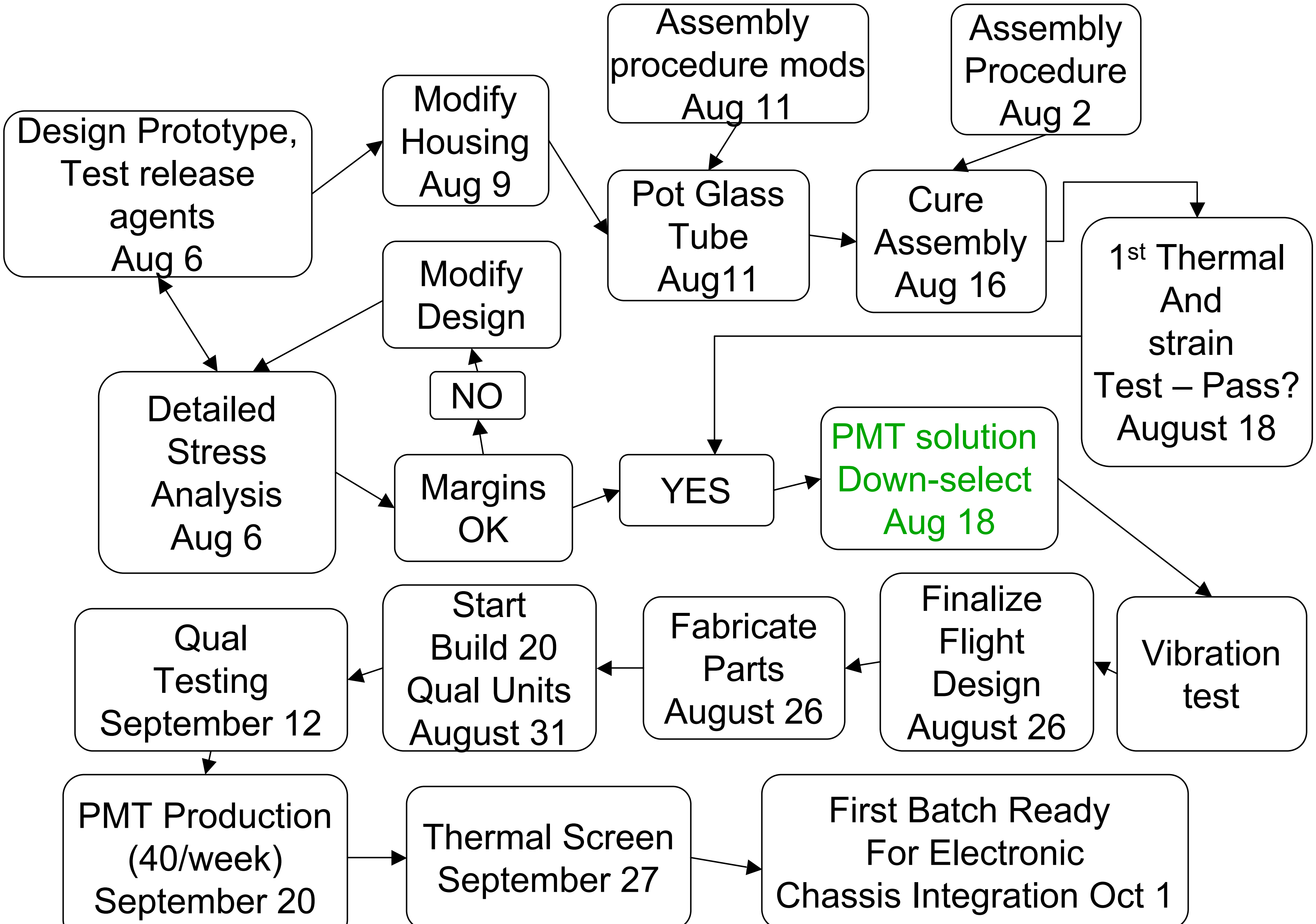
Strip version



ACD Phototube Breakage – De-bonded PMT Housing Design

- **Status:**
  - Analysis shows both are effective in reducing stress. The strip version has some minor stress riser concerns
  - 1 prototype of each bonded and successfully thermally tested Tuesday. Can not directly measure strain on glass.
  - Strain data showed de-bonding on both. Strip approach produced confusing data that would need to be pursued. Both <u>may</u> be showing some warm side strain increases due to RTV expansion
- **Actions:**
  - Vibration test

Alternate Design – De-bonded PMT Housing Design



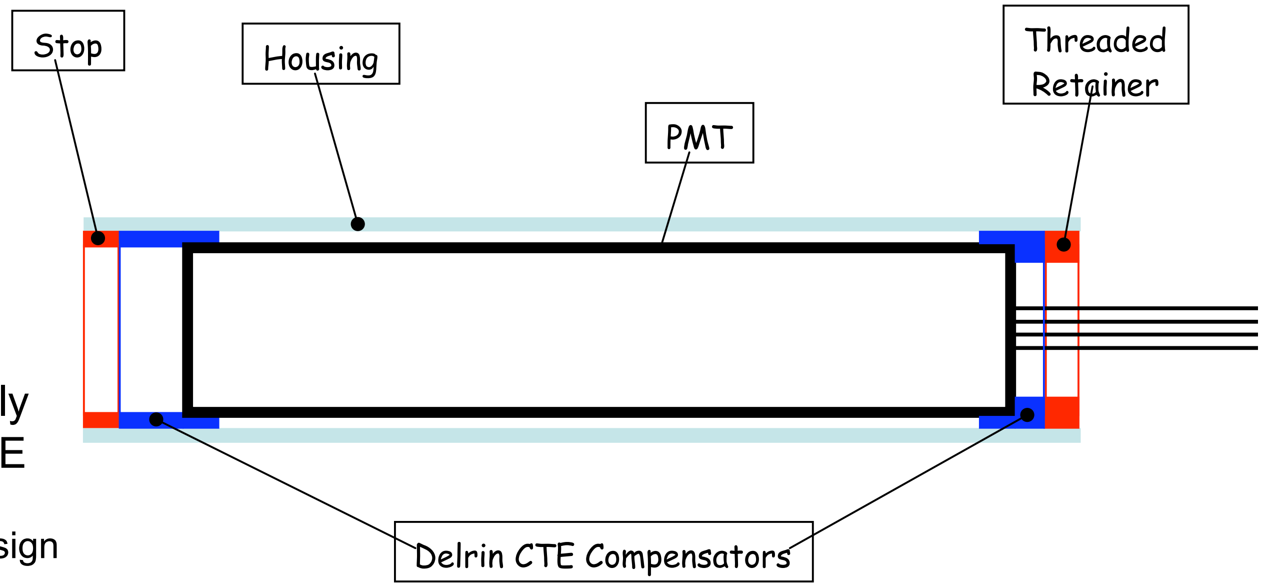
Mechanical mount - Partial CTE Compensation Option

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 and design modifiable if there is a problem
- Relatively easy assembly, and it can be converted to the spring compensation design anytime before Resistor Network assembly

Cons:

- CTE difference is not fully compensated. Force exerted will increase at cold extremes approximately 4X initial preload to 1500 psi
- Preload required on PMT. Should be in compression but tube dimension errors will likely cause small tensions
- Custom machined parts to match PMTs
- Very small (.002-.004”) radial motion could occur during vibration if preload is overcome

Mechanical mount - Partial CTE Compensation Option

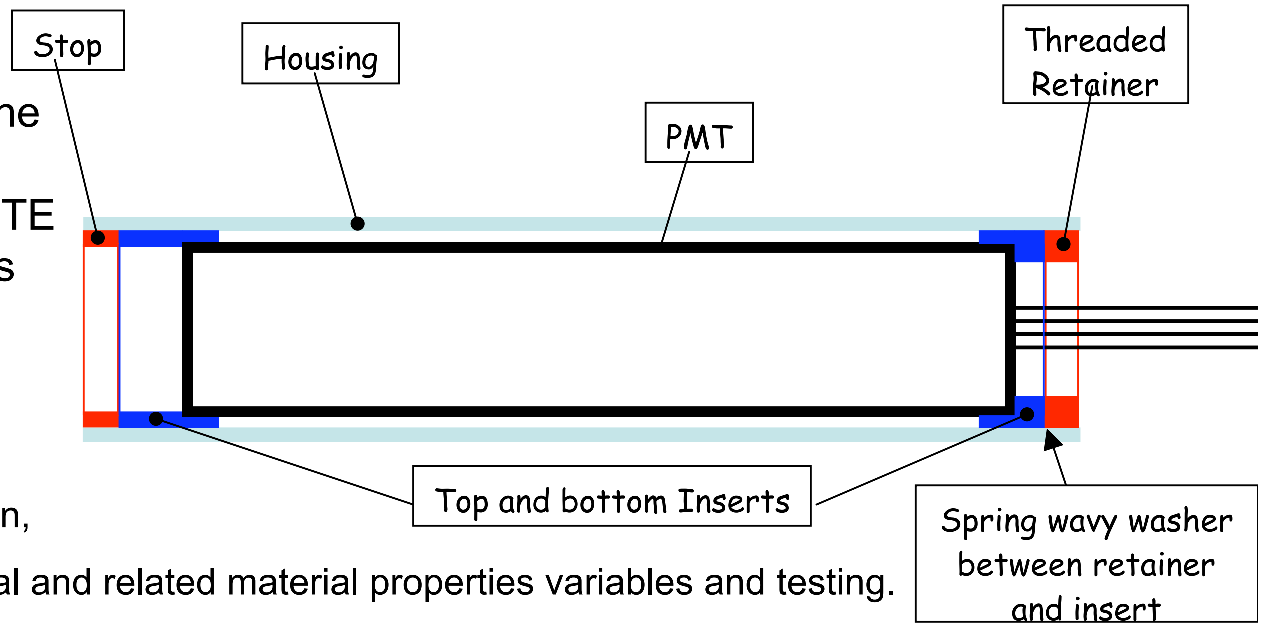
Status:

- Rapidly prototyped last week
- Room temperature prototype torque testing completed
- Stress analysis completed
- 1 prototype successfully tested with longitudinal strain measurements which were close to analysis prediction

Actions:

- Vibration test
- Confirm hoop strain with strain gauge

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, and modifications possible if there is a problem. Spring limits preload on PMT
- Relatively easy assembly, relatively easy assembly, and it can be converted to the CTE compensation design anytime before resistor network assembly

Cons:

- Spring constant will vary.
- Preload still required on PMT. Limited by spring so less of a concern. Should be in compression but tube dimension errors will likely cause tension.
- Very small (.002-.004”) radial motion could occur during vibration if preload is overcome, does it matter as long as clear fiber spring has throw left and leads are ok?
- Custom machined parts to match PMTs, strain not tracking analysis as well as CTE comp does, why?

Mechanical mount - Partial Spring Compensation Option

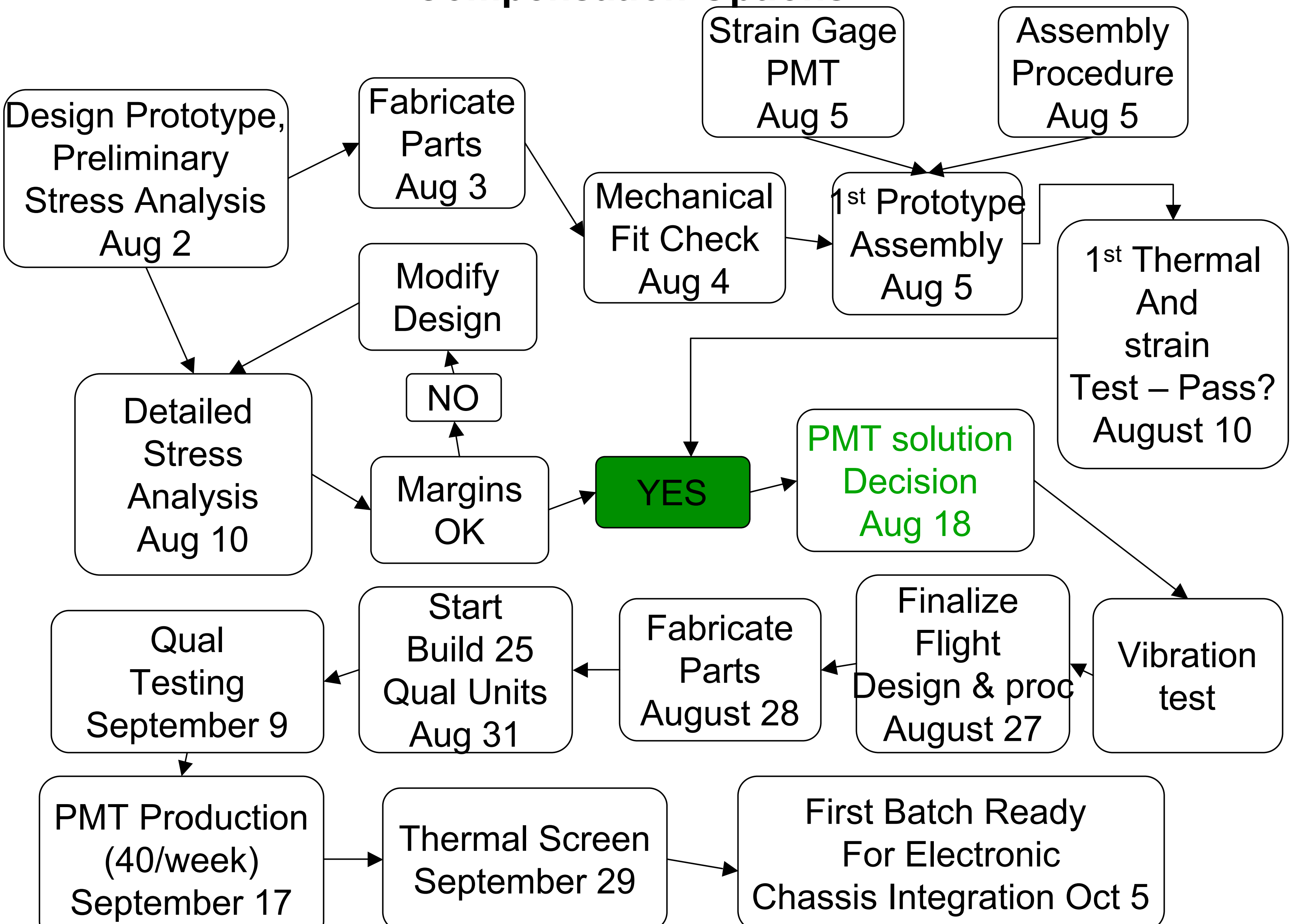
Status:

- Rapidly prototyped last week
- Room temperature prototype torque testing completed
- Stress analysis completed
- 1 prototype successfully tested with longitudinal strain measurements which were close to analysis prediction

Actions:

- Vibration test
- Confirm hoop strain with strain gauge

Mechanical mount - Partial Spring Compensation and CTE Compensation Options

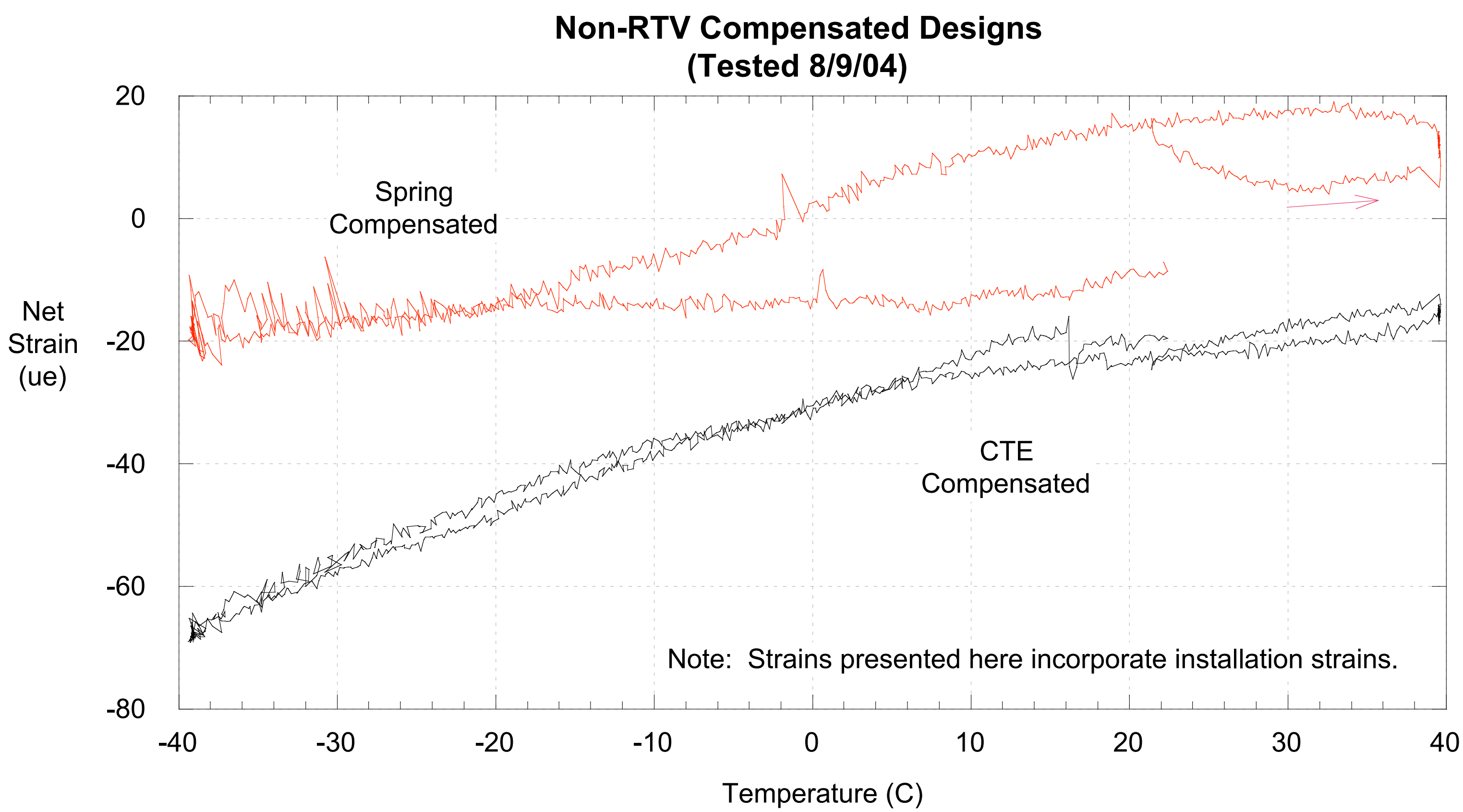


Solution stress comparison table

ACD PMT Design Solution Stress Comparison			
Design Option Description	**Max Relative Stress n=0.46 CTE=233 ppm/°C**	**Max Relative Stress n=0.495 CTE=387 ppm/°C**	**Comments**
Original potted design	467 psi (3220 kPa)	6535 psi (45055 kPa)	Maximum stress using RTV; on the inside of the glass tube
Notched potted design	18 psi (127 kPa)	33 psi (228 kPa)	Max stress same as glass and RTV only
0.25”-wide bonded strip design, fully potted tube	20 psi (136 kPa)	45 psi (311 kPa)	Max stress on the outside of the glass tube under bond line
0.5”-wide bonded strip design, fully potted tube	53 psi (365 kPa)	320 psi (2211 kPa)	Max stress on the inside of the glass tube under bond line
0.25”-wide RTV strip only	20.5 psi (141 kPa)	51 psi (352 kPa)	Max stress under RTV causes significant stress concentration
Mechanical design w/ spring compensation	n/a	-288 psi (-1985 kPa)	Longitudinal compressive stress with 10 lb (129 psi) preload added. Negligible hoop stress
Mechanical design w/ Delrin CTE compensation	n/a	-1320 psi (-9101 kPa)	Longitudinal compressive stress with 25lb (320 psi) preload added. Negligible hoop stress.
Glass tube and RTV only	18 psi (127 kPa)	33 psi (228 kPa)	Baseline minimum stress using RTV

Note: positive values are in tension, negative values are in compression.

Prototype strain tests – mechanical concepts



The decision based on what we know today

Both versions of the mechanical and de-bonded solutions appear to meet minimum selection criteria.

<u>We have decided to try and qualify the spring compensation method</u>

Pros:

- **The mechanical solutions show primarily compressive stresses rather than tensile. Glass is much stronger in compression. This is even more true of glass with significant flaws like ours. The spring method is less than 10% of the selection criteria stress (as are the two de-bonded solutions)**
- **The mechanical solutions offer what appears to be considerably faster production time.**
- **Of the mechanical solutions, the spring solution offers lower stress and built in preload margin.**
- **The spring solution can easily be converted to the CTE compensation solution by bottoming out the spring or removing it (they use the same parts other than the spring)**
- **The spring provides preload control – lowers intial preload and gives margin for preload release (warm temps or delrin creep_**
- **No RTV or other potting material and related material properties variables and testing**.
- **We are leery of putting the PMTs into a potted design (with RTV or any potting material). Not just because the challenges it poses are fresh in our memory, possibly giving us some built in bias. Potted solutions reduce flexibility to handle problems. The PMTs can not be easily removed and recovered, the design can not be modified if we run into trouble later using existing parts like the mechanical solutions can.**

The decision based on what we know today

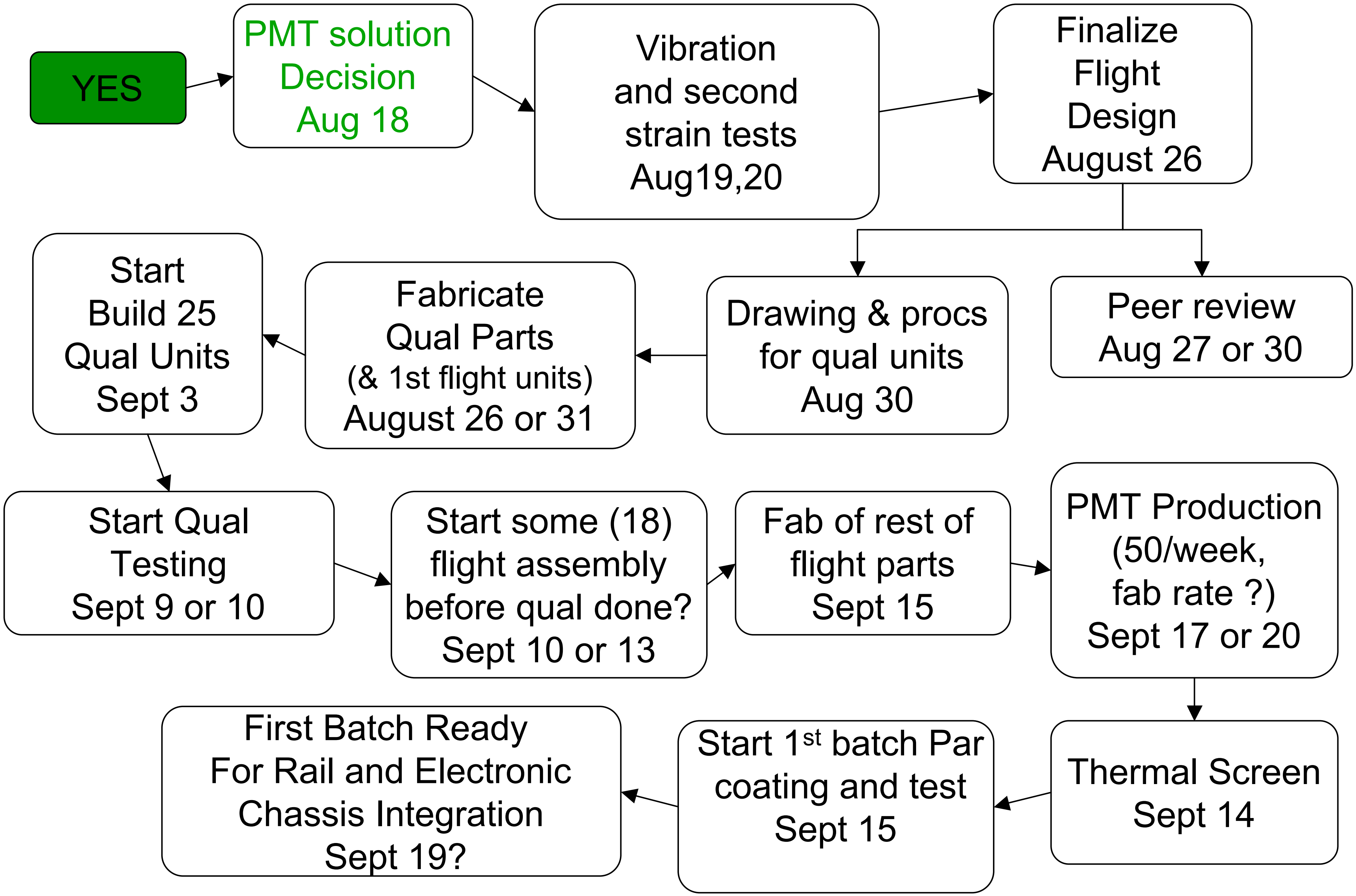
- **This flexibility could serve us well considering we still have to make it through a qualification program. Since four solutions appeared to meet minimum requirements, the flexibility and 'fixability' of the mechanical designs .**

- **There are some details and 'cons' in the design that need to be worked – we will reduce try and reduce vibration motion if preload is exceeded with design tolerance changes. We may need to certify springs. We want to know why the measured strain to analysis was more off than the CTE compensation method. We have to work out minor tacking and locking details , drawings and procedures for qual units.**

- **Our non mechanical back up approach (in case there is something we don't understand, some surprise in the mechanical designs) will be the groove de-bonding method. It is actually the absolute lowest stress solution. The CTE compensation method is also an easy backup if problems arise that are specific to the spring washer design, they are interchangeable in a way.**

- **Can use existing housing design**

Mechanical mount - Partial Spring Compensation and CTE Compensation Options - draft of more detailed future flow



What do we do with the already bonded PMTs?

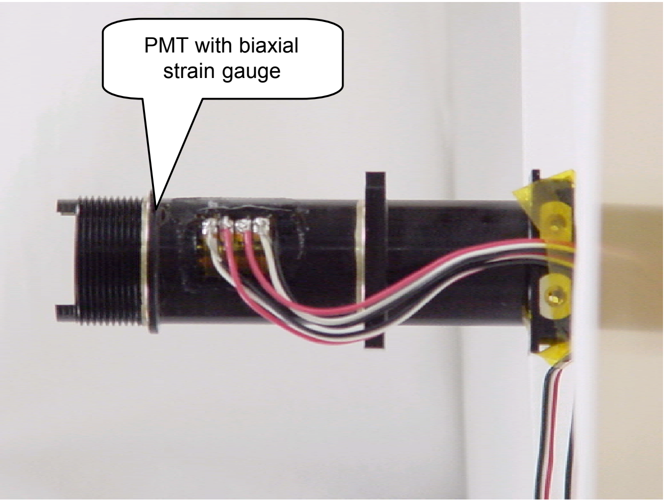
If viable they will be strain screened. All but the very low strain PMTs will be removed via the turn, peel and Dynasol method. They will be reassembled into the spring compensation method.

- **If the strain screening method shows it could be viable we will strain screen the bonded PMTs.**
- **The low strain PMTs (extrapolate to <1000 psi at -30C) would then be thermally screened and could fly as is.**
- **All others will be removed via the slow low load turning of the housing, peeling the remaining thin housing skin, and Dynasol off the RTV. This has been successfully tried twice.**
- **There could be drop out during the removal process. We have ordered additional spares.**
- **Because of the time involved these PMTs will take longer to process into new housings**

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)**

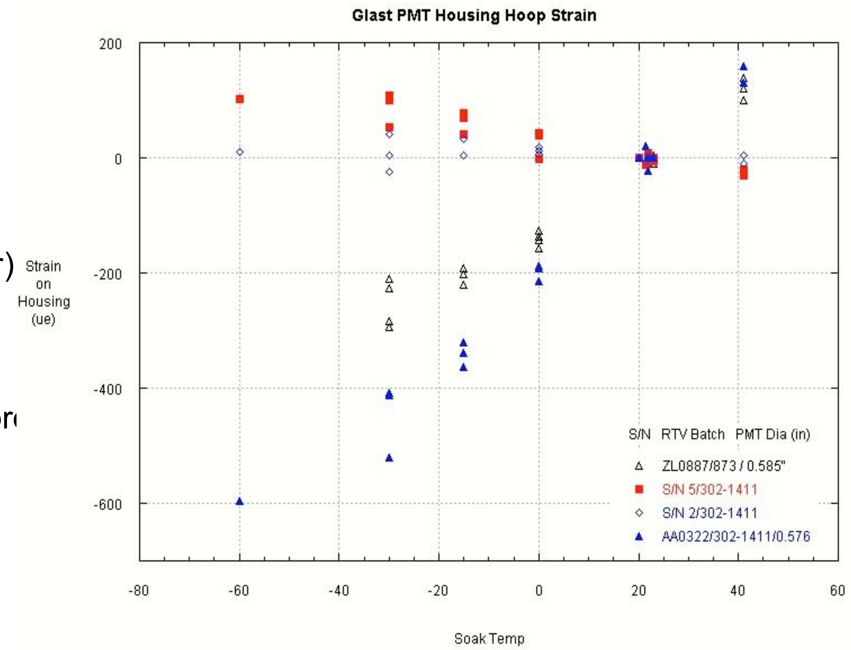


Pros:

- 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 thermal screening.
- Adhesive used to bond the gauges is a cyanoacrylate (outgasser)
- Rework potted phototubes that show higher stresses.



•Status:

- 4 PMTs shown suggest this is possible. Testing 9 tubes now to pr

•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.

Strain screening tests

For the six units tested the maximum strain rates and associated approximate stresses at -30C are
(ue/C & psi) - 0.5/250, 1.1/550, 1.2/600, 2.9/1450, 4.5/2250, 5.1/2550

PMT Ident	Gauge Location	Strain Rate	Temperature Range
		(_e/°C)	(°C)
AA 0190	Base	4.5	10 to 35
	Window	1.4	
ZL 1189	Base	0.5	
	Window	1.1	
AA 0188	Base	1.2	
	Window	0.7	
AA 0115	Base	-0.7	
	Window	0.5	
AA 0303	Base	5.1	
	Window	-0.8	
AA2096	Base	0.2	
	Window	2.9	
ZL 0887	Window	5.2	-30 to 40
AA0322	Window	8.1	-60 to 40
S/N 2	Window	-0.2	
S/N 5	Window	-1.5	

Screening and removal of Potted Phototubes