Mu2e Cosmic Ray Veto:
8.7: CRV Module Fabrication
"Follow up" on fabrication hours

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Content

- Review of factory labor estimate.
- Include breakdown of task estimates.
- Clarify a few points we failed to mention on Tuesday.
- Discussion of factory lifetime
- Extended support for lead technician

Personnel at the Module Factory

- Technician Leader: Factory design, prototyping, factory management (QA/safety), documentation, fabrication, …
- Mechanical Technician: Assist in moving into factory, building assembly stations, and fabrication efforts.
- Undergraduates: tedious tasks in the module factory: cleaning/de-burring components, spreading epoxy, QA checklists, …
- Uncosted graduate students, postdocs, and faculty: commission the QA tools, establish metrics, analyze data from QA measurements, and fill in where ever they are needed at the factory.

Personnel at the Module Factory

- About 7300 total hours of effort to fabricate 91 modules to Fermilab.
  - ~80 hours of fabrication effort per module.
  - ~54 hours of tech effort per module for fabrication.
- With full-time effort, about 6 modules per month can be produced in the module factory.
- 40% LOE in additional to hours above
  - 20% maintain factory
  - 20% administrative: inventory, QA data, …
- 40% contingency in additional to hours above
- Separate task for packing modules & loading truck:
  - 2 tech hours/models (20 hours per shipment)
- Separate task for managing module parts:
  - 1 hour per module

Primary steps for fabrication

1) Assemble di-counters: 4 tech hours
   - -- epoxy 32 pairs of counters together. < 10 min per counter pair.
   - -- spread epoxy on pairs and clamp full layer at once.
   - -- undergrad student could prep counters.
2) Fiber and fiber guide bar: 6 tech hours
   - -- apply epoxy to 64 FGB and fix in place with jig (~10 per hour).
   - -- undergrad student could thread 128 fibers.
3) Flycut: 8 tech hours
   - -- time consuming step with almost constant attention.
   - -- fiber imaging done during fly cut process.
4) Fiber QA: 4 hours
   - -- fiber transmission test of 32 di-counters.
   - -- < 10 min per di-counter, run test & record results

Primary steps for fabrication (cont…)

5) Counter manifold: 4 tech hours

-- insert counter motherboard and attach jig

(can be prepped in advance by U-grad)

-- simple install – 2 screws per manifold

6) Epoxy module: 6 tech hours

-- 32 di-counters, 5 AL sheets, lots of epoxy

-- requires two people for efficiency (tech + U-grad)

7) Module QA: 2 tech hours

-- techs move modules

-- post-doc performs QA

8) Crate: ~1 tech hour per module

-- Crates fabricated at local job shop

Summary: tech hours for fabrication

1) Assemble di-counters: 4 hours
2) Fiber and fiber guide bar: 6 hours
3) Flycut: 8 hours
4) Fiber QA: 4 hours
5) Counter manifold: 4 hours
6) Epoxy module: 6 hours
7) Module QA: 2 hours
8) Crate: 1 hour

Total: ~ 35 hours per module

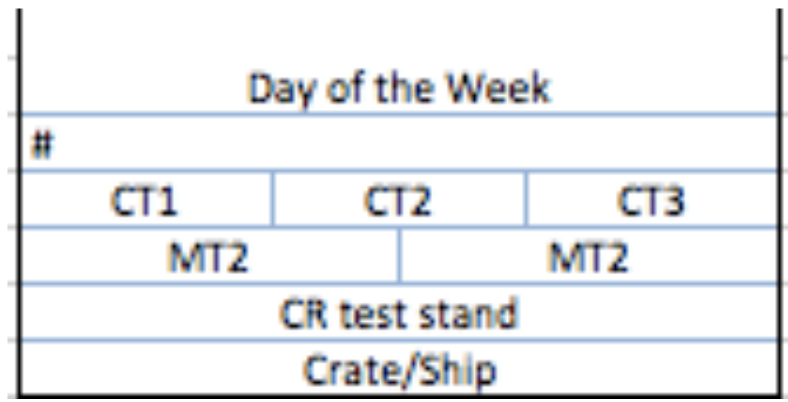
- additional 19 available: basic QA, prep, and surprises
- also 20% FTE to maintain factory
- also 20% for administrative effort
- also 40% contingency

Work flow at module factory

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1 di-counter	2 fiber, di-counter	3 cure, fiber, di-counter	4 cure, cure
5 cure, cure	6 flycut, cure, fiber	7 fiber QA, flycut, cure	8 manifold, fiber QA, cure	9 transition, manifold, cure transition	10 di-counter, transition, flycut module, transition	11 cure
12 cure	13 fiber, di-counter, fiber QA cure, module	14 cure, fiber, manifold transition, cure tranistion	15 cure, cure, transition transition, cure CR test stand	16 cure, cure, di-counter module, cure Crate (1)	17 flycut, cure, fiber cure, transition transition	18 cure cure
19 cure cure	20 fiber QA, flycut, cure CR test stand	21 manifold, fiber QA, flycut transition transition Crate(2)	22 transition, manifold, flycut transition CR test stand	23 di-counter, transition, fiber QA module, transition Crate(3)	24 fiber, di-counter, manifold cure, module	25 cure cure, cure
26 cure cure, cure	27 cure, fiber transition, cure transition	28 flycut, cure, transition transition CR test stand	29 fiber QA, cure, di-counter module, transition transition Crate(4)	30 manifold, cure, fiber cure CR test stand	31 transition, flycut, cure cure, transition Crate (5)	1 cure cure

Module 1
Module 2
Module 3
Module 4
Module 5
Module 6
Module 7
Module 8
Module 9
Module 10
Module 11
Module 12
Module 13
Module 14

Month 1
(DocDB 4197)



Work flow at module factory

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1 cure cure
2 cure	3 di-counter / fiber QA / flycut transition / module transition	4 fiber / manifold / fiber QA cure CR test stand	5 cure / transition / manifold transition / cure Crate(6)	6 cure / di-counter module / cure	7 cure / fiber cure / transition transition	8 cure cure
9 cure cure	10 flycut / cure / transition transition QA test stand	11 fiber QA / flycut / di-counter transition / module transition Crate (7)	12 manifold / fiber QA / fiber cure CR test stand	13 transition / manifold / cure transition / cure Crate (8)	14 d-counter / cure module / cure	15 cure cure
16 d-counter cure	17 fiber / flycut cure / transition transition	18 cure / transition / fiber QA transition CR test stand	19 cure / di-counter / manifold transition / module transition Crate (9)	20 cure / fiber / transition transition / cure CR test stand	21 flycut / cure / di-counter module / cure Crate (10)	22 cure cure / cure
23 cure cure	24 fiber QA / flycut / fiber transition / cure tranistion	25 manifold / fiber QA / cure cure CR test stand	26 transition / manifold / cure transition / transition transition Crate (11)	27 di-counter / transition / cure module / transition CR test stand	28 fibers / di-counter / flucut cure / module Crate (12)	29 cure cure / cure
30 cure cure / cure	31 cure / fibers / fiber QA transition transition					

Module 12 crated in less than 2 months!

Month 2

Day of the Week					
#					
CT1		CT2		CT3	
MT2			MT2		
CR test stand					
Crate/Ship					

	Module 1
	Module 2
	Module 3
	Module 4
	Module 5
	Module 6
	Module 7
	Module 8
	Module 9
	Module 10
	Module 11

Lag time in work flow

- 7 days are "free" on the counter assembly table over 2 month period
  - This work space is a bottleneck
    (this drove design of 4-layer table)
  - Fly-cutting a module is a full day of effort
    (but not a big deal if it bleeds into fiber QA)
- Many days free on the module assembly table
- Many days free on the cosmic ray test stand
- Crating only takes small effort per module
  (crates to be produced at local job shop)

There is a day or two of flexibility on transitions between work spaces except for the counter assembly table.

Optimizations

- We have presented the baseline fabrication plan
- The factory schedule was a planning exercise as a proof of principle that activities can occur in the planned factory at the estimated rate.
- There will be ample opportunity to streamline the plan based on what we learn from prototypes and the pilot phase. Examples:
  - Staggered work days for technicians
  - Evening prep by undergraduates or post docs
  - Optimizations of activity combinations in a work day
  - Which work days benefit most from a third person
  - Preparing several modules worth of di-counter in advance of production
  - …

Tech vacation and unexpected absence

- We plan to have two post docs stationed at UVA during the fabrication effort. (also two faculty)
- Post docs will maintain the CSC test stand and perform module QA.
- Group members will be trained in all steps of the fabrication and available to fill in for tech absence and if production falls behind schedule.

Prototyping was an important part of designing our plan and will be critical for for fine tuning of the plan!

We have built dozens of counter prototypes and a module prototype and have plans to build 5 more module prototypes.

Prototype Plan

- Mechanical prototype (early FY15):
  - 4.7 m long; No electronics
  - Time and motion studies; handling modules
  - Test/practice epoxy application
- Two "short" (cryo-length) electronics prototypes (FY15):
  - Outfitted with electronics
  - Study mounting techniques
  - Test bed for electronics
- Two "pre-production" prototypes (FY16):
  - Outfitted with electronics
  - Production scintillation and fiber
  - Shipped to Fermilab to test installation and mounting procedures

Factory Lifetime

- Extending the factory life beyond planned production was suggested.
- The factory, as designed, is optimized for large-scale production.
- The fly-cutter and QA devices and some jigs are the primary custom tooling required to make an extra module or two. These will be kept at UVA.
- It will be possible to produce a module or two at UVA if this need is discovered after factory breakdown.
- If there were some catastrophic event and a large fraction of the CRV needed to be replaced a new factory would be required.
- Given the costs involved, we don't think extending the life of the production factory beyond production is reasonable.

Lead Technician

- It was suggested the it would be best to keep the lead technician on staff through installation.
- We would love to keep him if we can find work on other projects during that time.
- That being said, we believe that the scientific staff will be experts on all steps of fabrication by the end of the production period.
- All production steps will be well documented and we are confident that in an emergency we will be able to build additional modules without the lead technician.
- We will look for oportunities to keep the tech on staff, however given the costs involved, we don't think supporting the tech through instillation should be the baseline plan.

Summary

- The labor plan for the module fabrication factory is well defined and most steps have been (or will be) confirmed with prototype fabrication experience.
- The counter assembly table space is a bottleneck due to several fabrication steps and epoxy cure time. There is flexibility in scheduling daily activities at the other stations.
- U-grad and uncosted scientific effort will be available to fill in when needed during fabrication: tech vacation, illness, schedule variations…
- There is a 40% FTE in addition to fabrication labor for maintaining the factory and administration tasks.
- In addition, there is a 40% contingency on the labor estimate.
- We think the estimate is defensible.