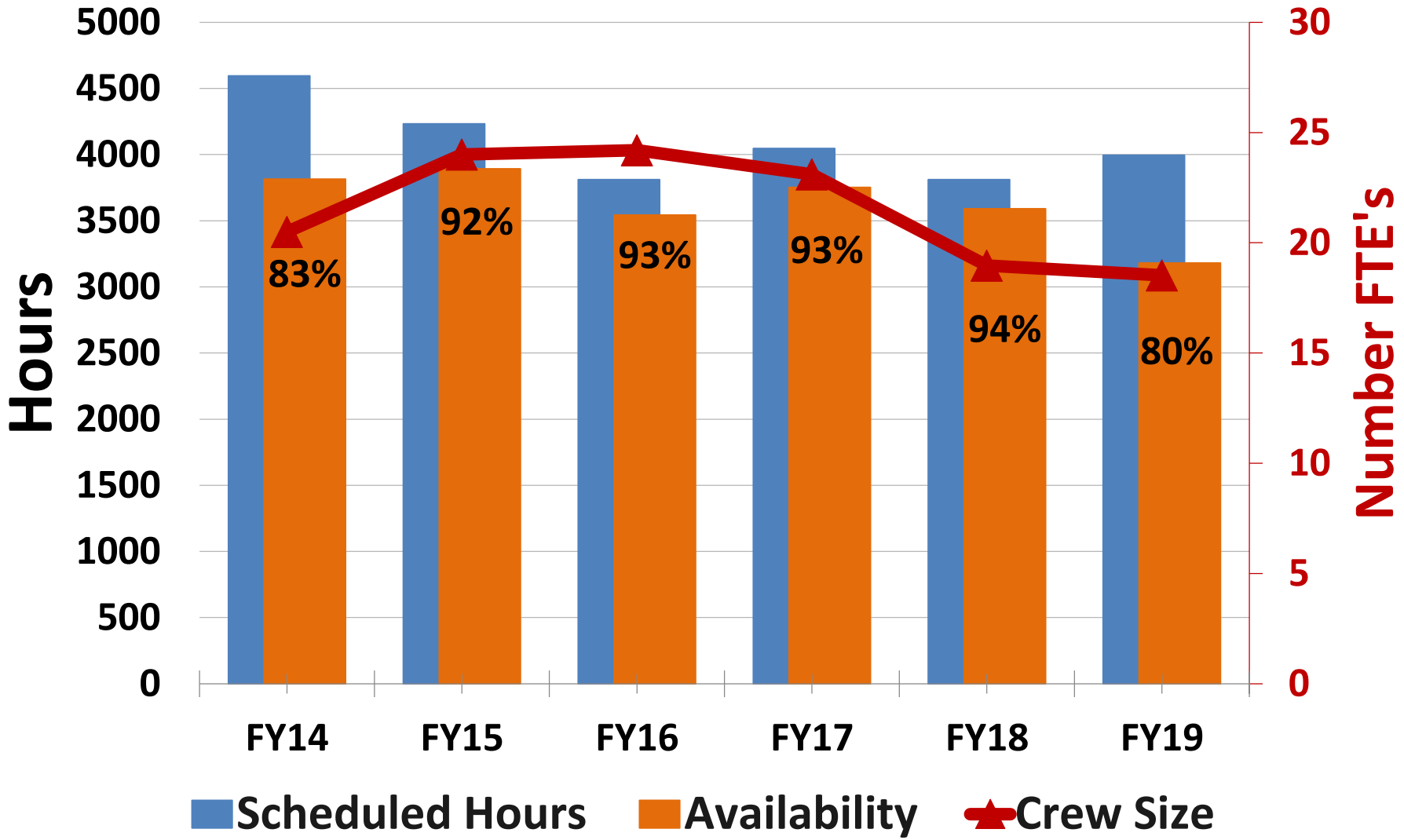
88-Inch Cyclotron Facility Maintenance & Reliability

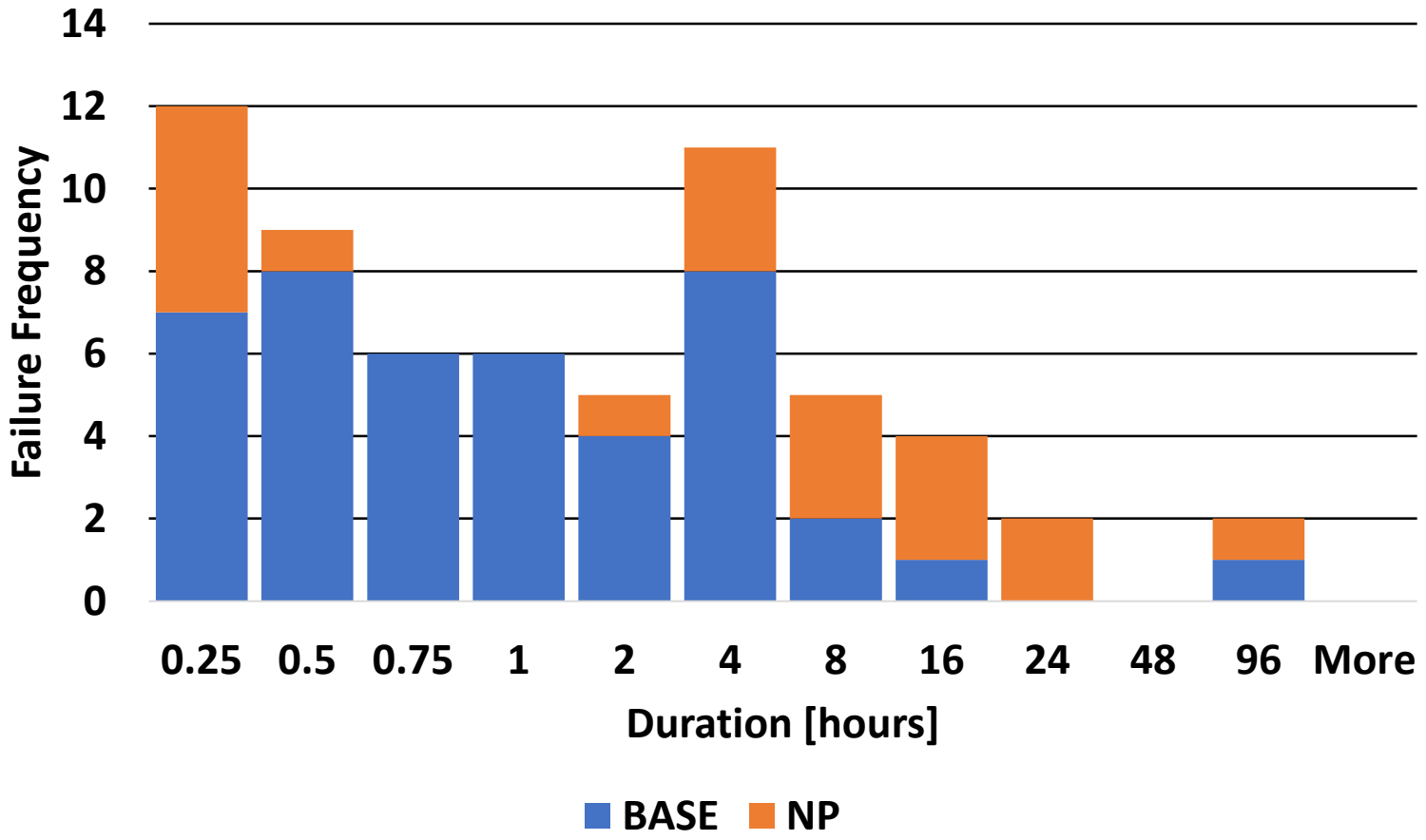
BERKELEY LAB

Brien Ninemire

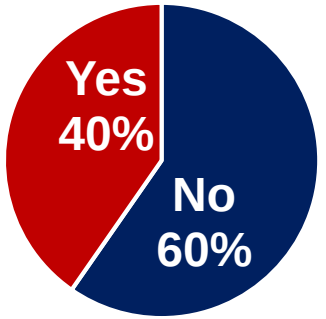
88” Cyclotron Availability & Crew Size History



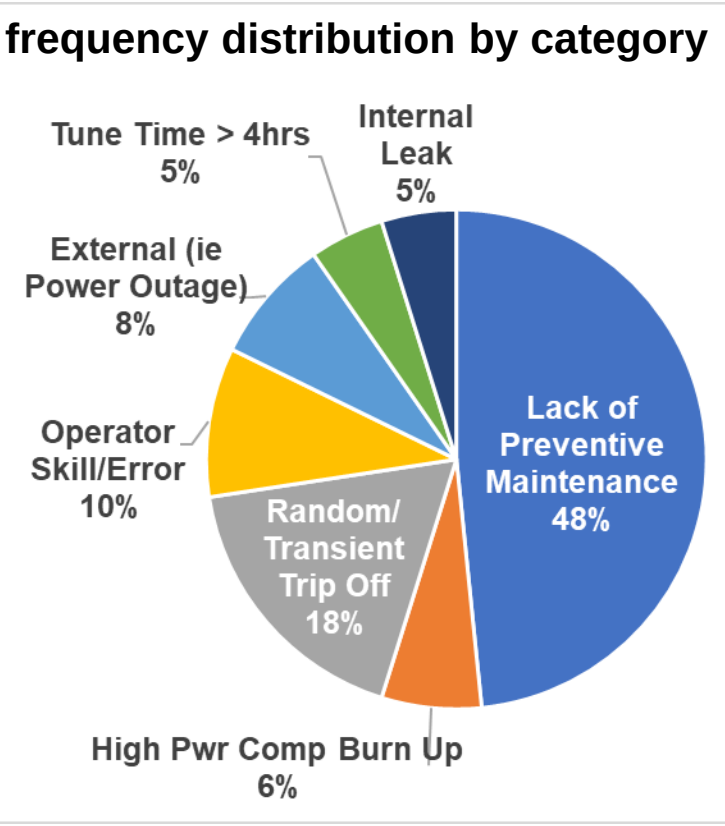
FY17 Beam Delivery Failure Analysis



"Does the failure preclude any/all beam delivery?"

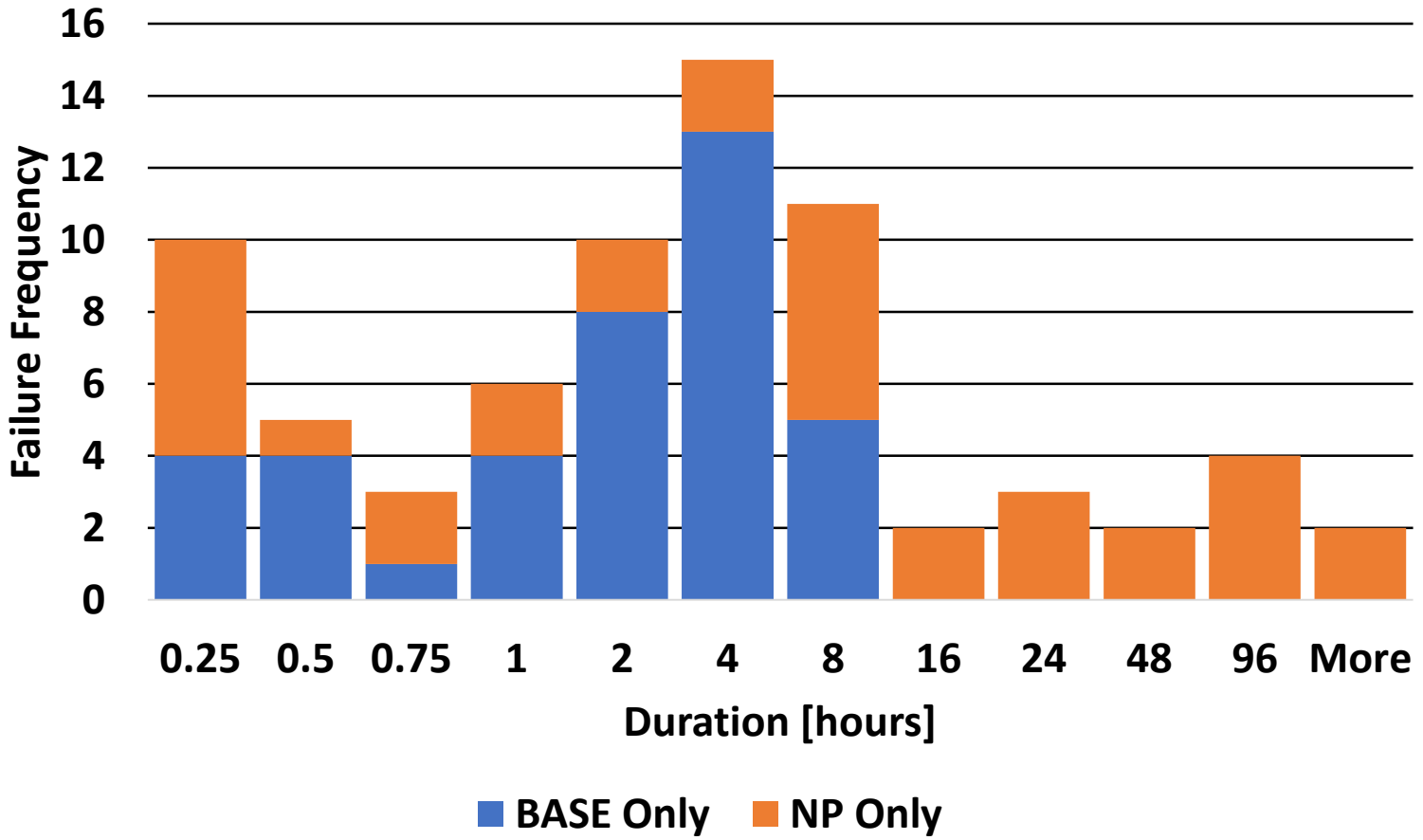


Failure frequency distribution by category

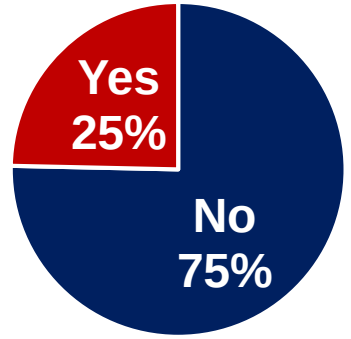


Scheduled Hours: 4047	Availability: 93%	Crew Size: 23.1
Avg. Experiment Duration: BASE = 33 hours, NP = 89 hours		

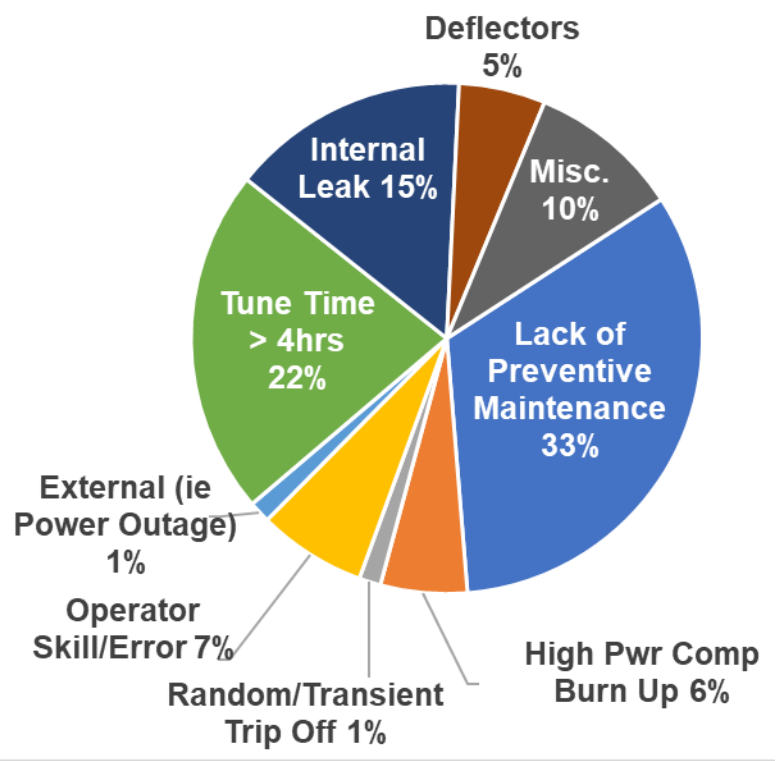
FY19 Beam Delivery Failure Analysis



"Does the failure preclude any/all beam delivery?"



Failure frequency distribution by category

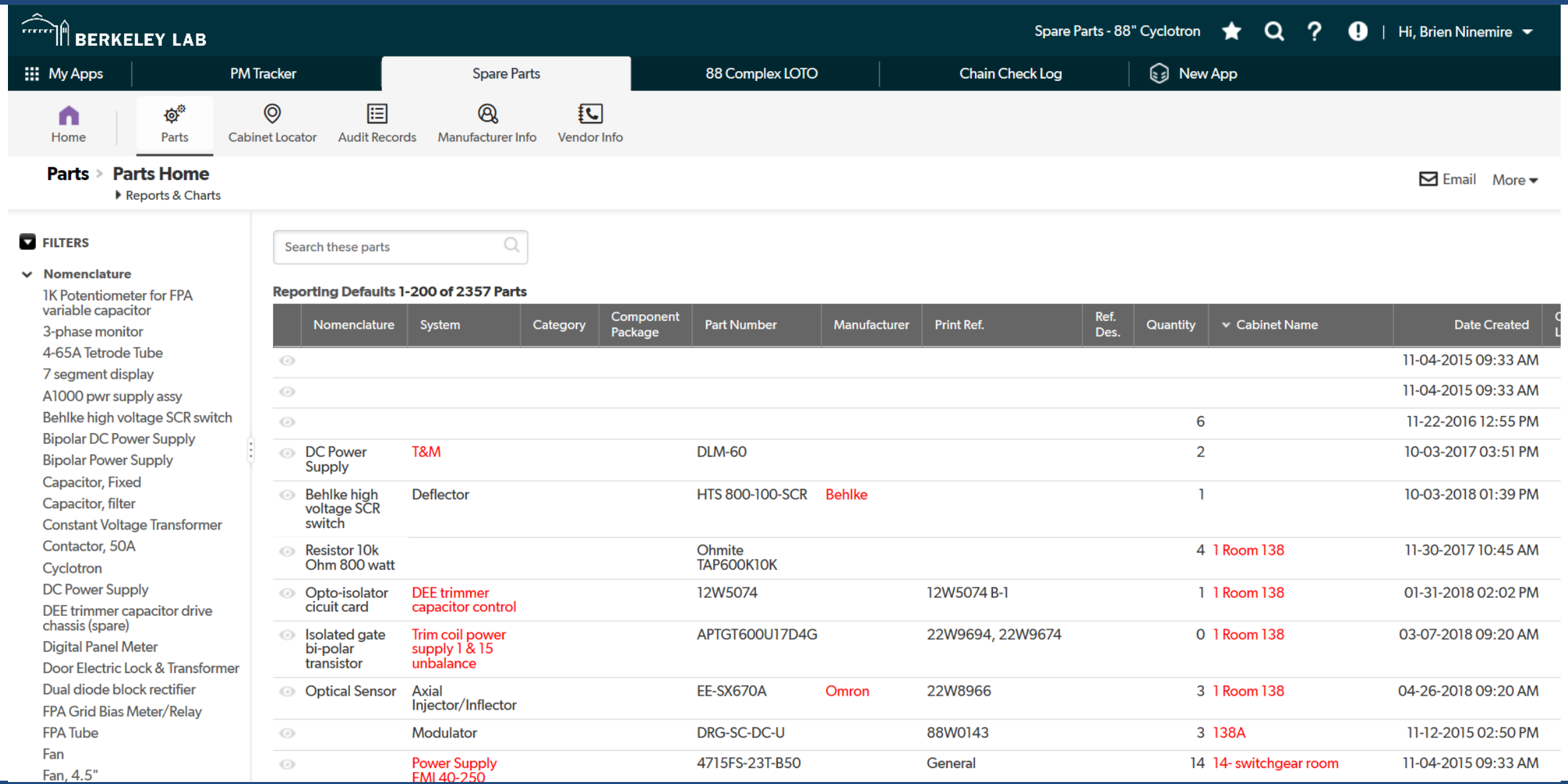


Scheduled Hours: 3996	Availability: 80%	Crew Size: 18.5
Avg. Experiment Duration: BASE = 49 hours, NP = 106 hours		

Responses to the 2017 Operations Review

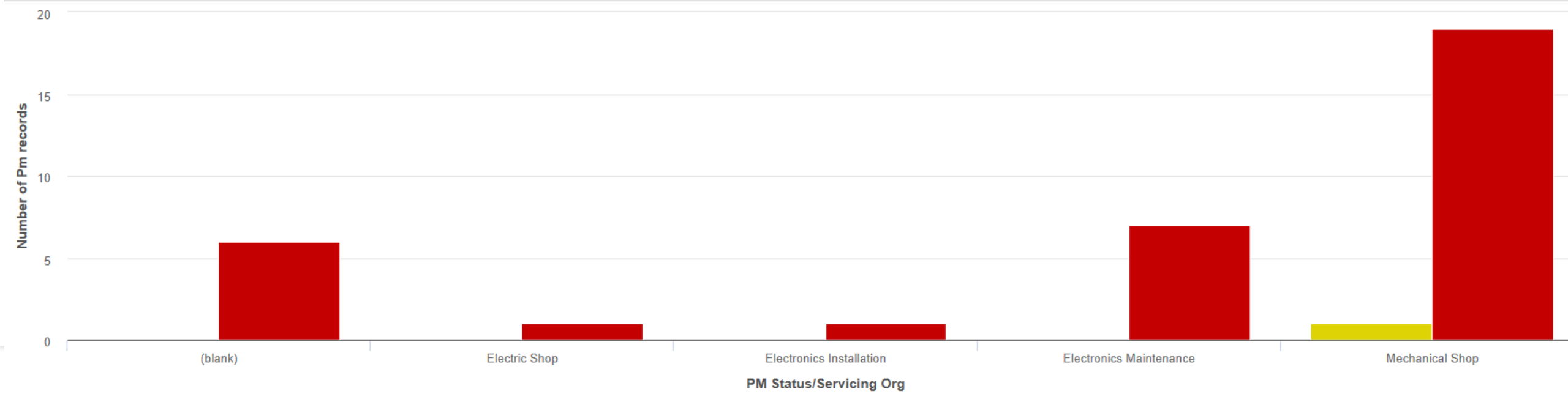
1. Implementation of a spare parts inventory database
2. Implementation of a preventive maintenance (PM) database
3. Development of a strategic plan for spending on maintenance, M&S and investments to improve reliability

New Facility Spare Parts Inventory Database



New Facility Preventive Maintenance Tracking System

At Risk PM by Servicing Org



	Nomenclature	Equipment Type	Part#	Serial#	DOE#	PM Due
(empty) (22 Pm records)						
UPDT	Scroll Pump	Scroll Pump	NXDS10i	180436236		01-01-1971
UPDT	Scroll Pump	Scroll Pump	NXDS10i	180400531		01-01-1971
UPDT	Cryo Pump, 1	CRYOGENIC PUMP	CP-8	16D611267	6610703	01-01-1971
UPDT	#2 CRYO PUMP 8 LOW PROFILE ISO FLANGE	CRYOGENIC PUMP	CP-8LP	1572		01-01-1971
UPDT	#3 CRYO PUMP 8 ISO FLANGE	CRYOGENIC PUMP	CP-8	1514		01-01-1971

Sample of PM Records in Database

PM Due	Nomenclature	Equipment Type	Manufacturer	Part#	Serial#	DOE#	PM Date	Performed By	Servicing Org	Record ID#	Attachment	Date Created
	Mechanical Pump	Pump							Shop			
05-09-2019	Alcatel Mechanical Pump	Mechanical Pump	Alcatel	1015 SD	359056		05-09-2018	Perry, Tom	Mechanical Shop	59		05-15-2018 08:01 AM
05-09-2019	Alcatel Mechanical Pump	Mechanical Pump	Alcatel	1005 SD	613928		05-09-2018	Perry, Tom	Mechanical Shop	60		05-15-2018 08:59 AM
05-10-2019	Alcatel Mechanical Pump	Mechanical Pump	Alcatel	2015	251759		05-10-2018	Perry, Tom	Mechanical Shop	61		05-15-2018 09:26 AM
05-11-2019	Leybold Trivac Mechanical Pump	Mechanical Pump	Leybold	D16B	91265-01		05-11-2018	Perry, Tom	Mechanical Shop	62		05-15-2018 09:29 AM
05-14-2019	Scroll Pump	Scroll Pump	Edwards	XDS35i	056259354		05-14-2018	Bell, Brian	Mechanical Shop	99		03-15-2019 02:38 PM
07-05-2019	Venus Extraction Power Supply	Power Supply	Glassman	PS/EQ040P0Y09	N318109-01NR111108		07-05-2016	Rogers, Craig	Electronics Maintenance	12		09-21-2016 09:54 AM
07-10-2019	M41/42 Magnet Power Supply, Fan Filter	Air Filter					07-10-2018		Electronics Maintenance	63		06-27-2018 03:43 PM
07-17-2019	Scroll Pump	Scroll Pump	Anesta Awata	ISP-250-C	RF-879		07-17-2018	Bell, Brian	Mechanical Shop	66		07-23-2018 08:14 AM
07-20-2019	DC Power Supply	Power Supply	Electronic Measurements, Inc.	00481562	98M-1831		07-20-2018	Rogers, Craig	Electronics Maintenance	64		07-20-2018 09:33 AM
07-20-2019	Venus Injection ground Hook	Ground Hook		Lo-Z Ground Hook #22	Lo-Z Ground Hook #22		07-20-2018	Cronander-Ford, Brendan	Electronics Installation	122		01-30-2020 07:15 AM

Detail of a PM Record in Database

PM Records > **PM Record #55**

▸ Reports & Charts

Equipment Information

Nomenclature	FPA Driver Amplifier
Part#	A1000
Serial#	
Hours Total	
Manufacturer	ENI
DOE#	6132663
Equipment Type	RF Amplifier
System	RF
Print	
Ref Des.	
P/L Section	

PM Data

PM Date	03-25-2018
PM Due	03-25-2019
PM Due (Hours)	
Performed By	Small, Scott
PM Notes	-- [MAR-25-18 Scott Small] ---------- - Repaired bad solder joints, replaced bad transistors. - Upper right PA8 emitter resistors melted off board, replaced board. - Series regulator board feeding upper right PA8 heat damaged, replaced series regulator board and transistors. - Current limit potentiometer and IC 723 circuit heat damaged on upper power supply regulator board for PA8, replaced potentiometer and IC 723 circuit. - IC 723 circuit damaged on lower power supply regulator board for PA8, replaced IC 723 circuit. -- [MAY-01-19 Robert Albright] ---------- Carried forward from duplicate record: PM'd by Scott Small 3/2016
Attachment	A1000 #6132663 Maintenance 03252018.pdf
Location	Highbay [JUN-04-19 Robert Albright] Highbay (88-192)

Equipment Management

PM Interval	365 days
Days Remaining	-340
PM Status	Overdue
Servicing Org	Electronics Maintenance
PM Interval (Hours)	
Service Type	
Equipment Status	
Parts Kit Req'd	
Equipment	55
Priority	
Special Conditions	

Asset Management

Life Expectancy (Hours)	
%Hours Accumulated(%Hours)	
Operational Category	

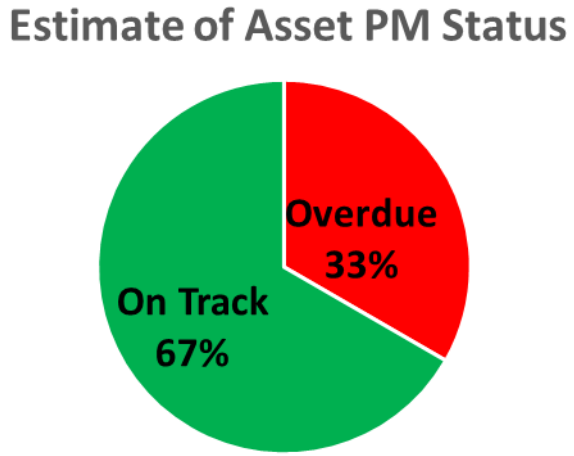
Summary of PM's Performed – Est 33% of Assets Overdue for PM Now

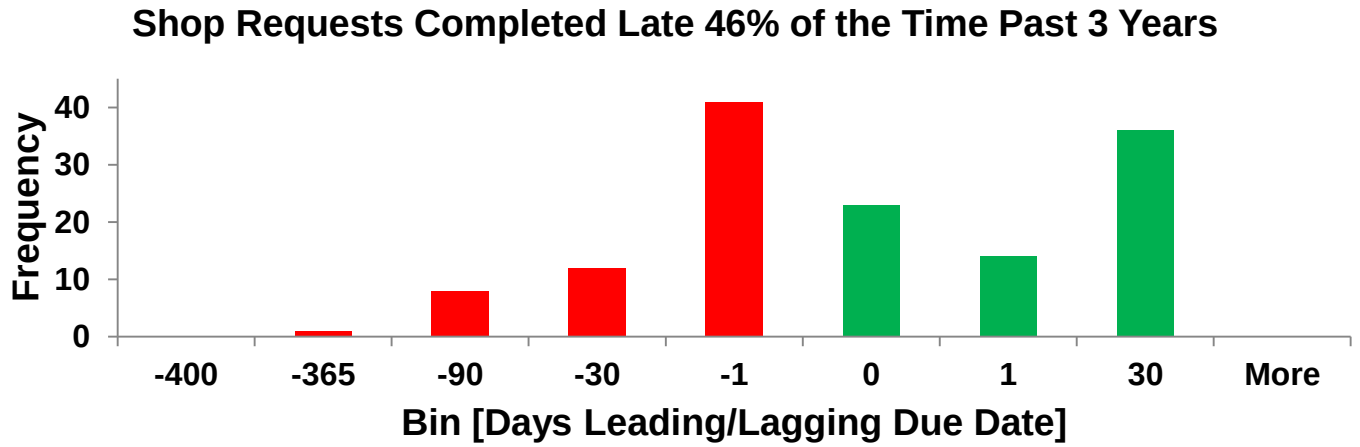
- Rebuild vacuum pumps (mechanical, scroll, cryo and turbo) and controllers
- Rebuild cryo-pump helium compressors
- Cleaning, testing and component replacement in power supplies
- Ground hook testing and fixing
- Vacuum gauge maintenance (replace filaments, fix controllers, test)
- Cooling circuit hose and gasket replacement
- Clean/Rebuild/Replace cooling water circuit flow-switches, flow-gauges and filters
- Cryo-plant helium liquefier (1430) engine deep clean, lube and tune-up
- Vault and cave door motor and hydraulics maintenance
- Heavy electrical gear maintenance (very large power supplies, transformers, rectifiers, etc.)
- Electrical distribution panel breaker maintenance/replacement
- Personnel Protection System & facility cross-connect logic relays on replacement schedule

Tech Allocation

Prioritized List of Tech Responsibility:

1. **Reactive Maintenance:** Highest priority. Drop everything and fix that which prevents current experiment from proceeding
2. **Planned Repairs and Upgrades:** Installation of replacement pumps, power supplies, etc.
3. **Fabrication of new Ops & Experimenter assets (Shop Requests):** e.g. targets, detectors/mounting, ion source ovens, shielding, data acquisition racks & chassis', etc.
4. **Preventive Maintenance:** Lowest priority, fill-in work when there is time





Hybrid Operator-Technicians

Existing Accelerator Operator Tier Structure		
650.1 Accelerator Operator	650.2 Principle Accelerator Operator	650.3 Operator Specialist
These are union positions for collective bargaining (UPTE)		
These job category codes are presently uniform for all LBNL accelerator operators (88, ALS, BELLA)		

- **An Operator-Tech takes the Specialist one step further**
  - A fully qualified operator hired at or trained to professional proficiency in a mechanical and/or electrical discipline
- **Operator-Techs could provide surge capacity to Mechanical and Electrical Groups**
  - Assist with overdue PM's and Shop Requests during their regular shift overlap with the other Operators (when not needed to run the cyclotron)
- **Can be redirected back to the Control Room as needed**
  - to cover for unplanned operator absence and to assist with BASE tunes to mitigate failures due to excessive tune times (> 4 hours)

Hybrid Operator-Technicians (cont.)

- **Potentially reduces need to recall techs during nights and weekends**
  - Potentially provides off-shift capacity for electrical switching, LOTO'ing and safety watch
  - Enhanced off-shift troubleshooting and repairs, reducing failure duration

- **Improved utilization of operator effort**
  - Excess of operators for 5500 hours run scenario would be far better utilized for maintenance during major shutdowns

Hybrid Operator-Technicians (cont.)

- **Where we are at now**
  - Our current Specialist has previous work experience in electrical and electronic maintenance, has been acting as an EM and Qualified-Electrical-Worker 2 (QEW-2 for switching and LOTO's) on shutdowns for a few years now
  - Identified our Principle Operator as good candidate for a Controls Engineer Hybrid Operator-Tech
  - Finding a mechanically inclined Operator-Tech would round out the supplemental staff
  - Don't anticipate resistance from the union
  - Would need LBNL HR and ALS buy-in?

Identified Single Points of Failure

1. Water leaks inside the cyclotron (from aging cooling lines)
2. A1000 drivers for RF system final power amplifier (replacement boards are no longer available)
3. Cooling tower replacement (system is beyond its design life)
4. The LN distribution system has trouble with its guard vacuum. If it fails, we lose access to VENUS until the system is repaired (many months)
5. Single helium compressor (vacuum)
6. Single Final Power Amplifier (FPA)
7. Water leaks outside the cyclotron (from aging cooling lines)
8. Aging wiring between the cyclotron and the power pad
9. An old Personnel Protection System (PPS) for which we can no longer purchase parts
10. Old power supplies for the beamline magnets
11. Spare 28 GHz gyrotron for VENUS
12. Old blower responsible for air exchange in the Vault
13. Lack of a spare modulator

Opportunities to Improve Reliability with Added Redundancy

Hot-swappable systems to minimize downtime

1. Deflector rails (new set of aluminum rails, cost: $100k)
2. Spare Final Power Amplifier (cost: $125k)
3. New helium compressor (cost: $350k)
4. Portable spare beamline power supplies (cost: $200k)
5. Spare modulator (cost: $500k)
6. Spare helium refrigerator (cost: $650k)

Identification of Risk

Reliability & SPOFs Lists

Categorized by
- preventive maintenance
- obsolete systems
- single points of failure
- reliability improvements

Categorized by mission:
- NP Only
- BASE Only
- Mutual

Risk Matrix	Low	Medium	High	**Probability**
	< 1%	1% to 10%	> 10%	
Low (days)	1	1	2	
Medium (weeks)	1	2	3	
High (months)	2	3	3	
Impact				

Prioritized investment list w/ timetable

Application of Risk Matrix Results in Prioritization of Investments

Risk Description (or condition to repair)	Impact	Probability	Risk	Mitigation	Type of Project	Shared cost?	Mitigation Cost to Prevent or Recover (k$)	Time to Implement Mitigation
Basement water loop failing because of corrosion	high	med	3	Repair severly corroded water headers in the Pit	Preventive maintenance	yes	50	3 months
Spare Final Power Amplifier	high	high	3	Spare final power amplifier	Investment	BASE	125	6 months
A1000s have failed, no longer serviceable (replace)	high	high	3	Go to a new vendor	Investment	yes	250	4 months
Old wiring below cyclotron fails	high	med	3	Replace wiring below cyclotron, several other areas, insulation failing	Preventive maintenance	yes	250	2 years
Mild to Serious water leak destroying cyclotron vacuum	med	high	3	64kl/s Turbo/cryo pump array (diffusion pump replacement), outrun WATER LEAKS	Investment, funds in hand	yes	300	1 year
LN guard vac failure	med	high	3	Repair/replace LN guard vac	Repair	Yes, AIP	500	1 year
Cooling tower is failing	high	high	3	Cooling tower, replace or repair	Repair	BASE, AIP	600	1 year

For a More Detailed Breakdown of Risk/Investment Prioritization Please Refer to the 2020 88” Cyclotron Strategic Plan Pages 18-19

SPOFs and Redundancies We Are Currently Working On:

- ✓ Purchased a New Drive Amplifier ($250k)
  - A modern RF drive amplifier has been purchased as an A1000 replacement (approx. 4 mo. manufacturer lead time). Spare parts, documentation and service training will be available for the foreseeable future.
- ✓ A spare RF Final Power Amplifier (FPA) cabinet has been built ($125k)
  - Already have several spare primary tubes to use. AC blocking capacitor spare already on hand. Will need to build a few custom components and order several “off-the-shelf” electronic components to complete assembly and rotate into service this fiscal year.
- ✓ Replacing a portion of the LN distribution system now (VENUS service, $50k so far).
  - Will stagger replacement of the cyclotron, cryo-plant, caves and lab space LN service over a longer period using a graded approach.
- ✓ Purchasing a New Cooling Tower (~$600k)
  - Funds allocated for a replacement cooling tower. In negotiations with Procurement, the manufacturer and a construction contractor.
- ✓ Developing a plan to replace a short section of the cooling water basement loop supply and return headers this next summer shutdown ($50k)
- ✓ LBNL Main Machine Shop fabricating a spare set of deflector rails out of aluminum now ($100k)
  - Will install and test performance at earliest opportunity (likely next summer shutdown).

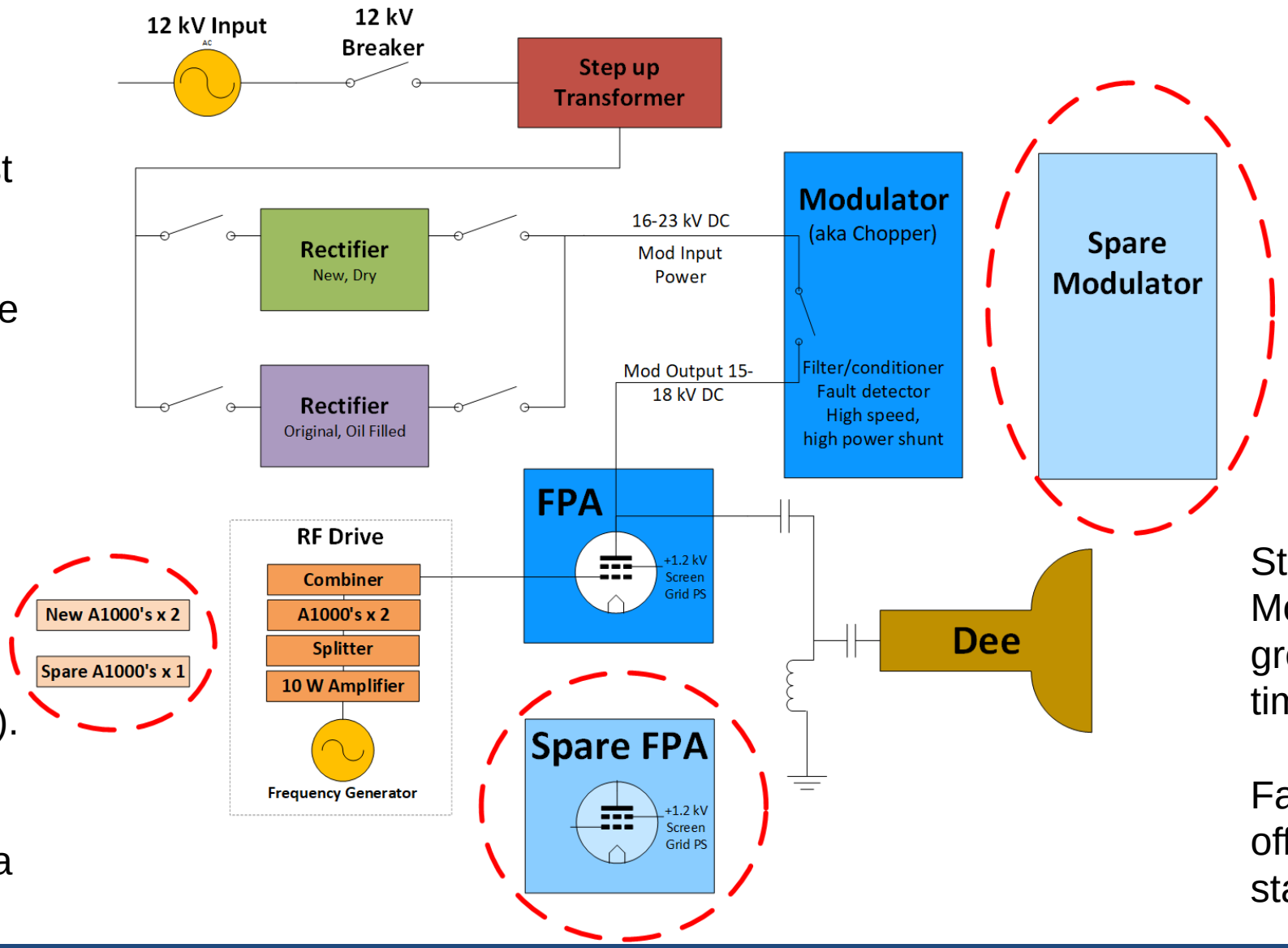
Cyclotron RF System Diagram

The Modulator, Final Power Amplifier (FPA) and drive A1000 amplifiers are the most complex subsystems.

They frequently require reactionary maintenance/repairs.

Demonstrating new drive amplifier replacement to A1000 (modern product line, readily available parts).

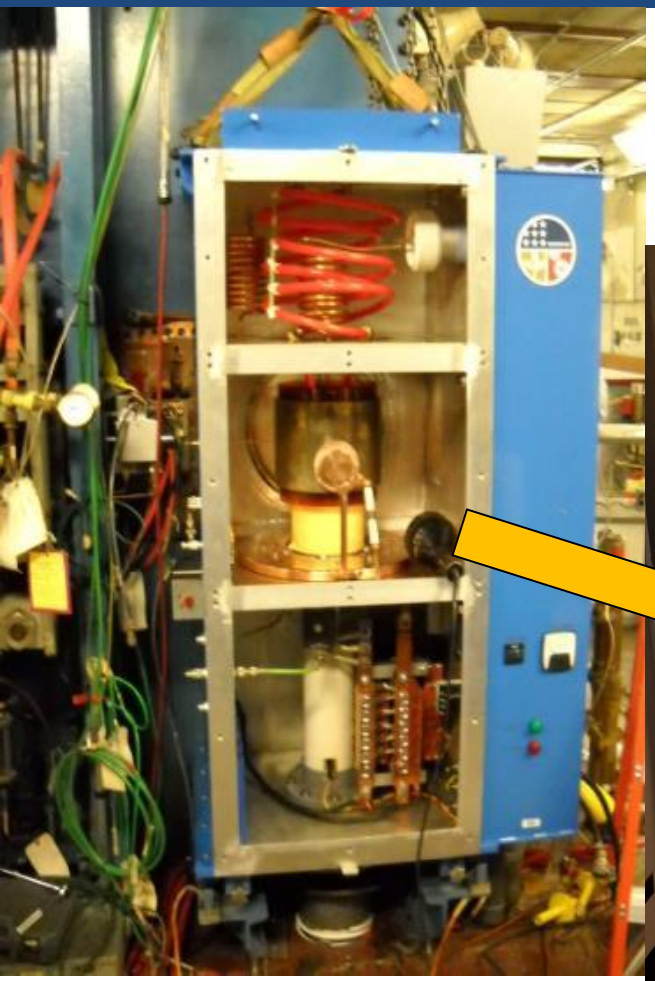
Will procure two more units if successful for a complete set.



Staging a spare Modulator and FPA will greatly reduce beam time loss due to failure.

Failed units repaired offline then rotate into standby.

Facility Investments In Progress

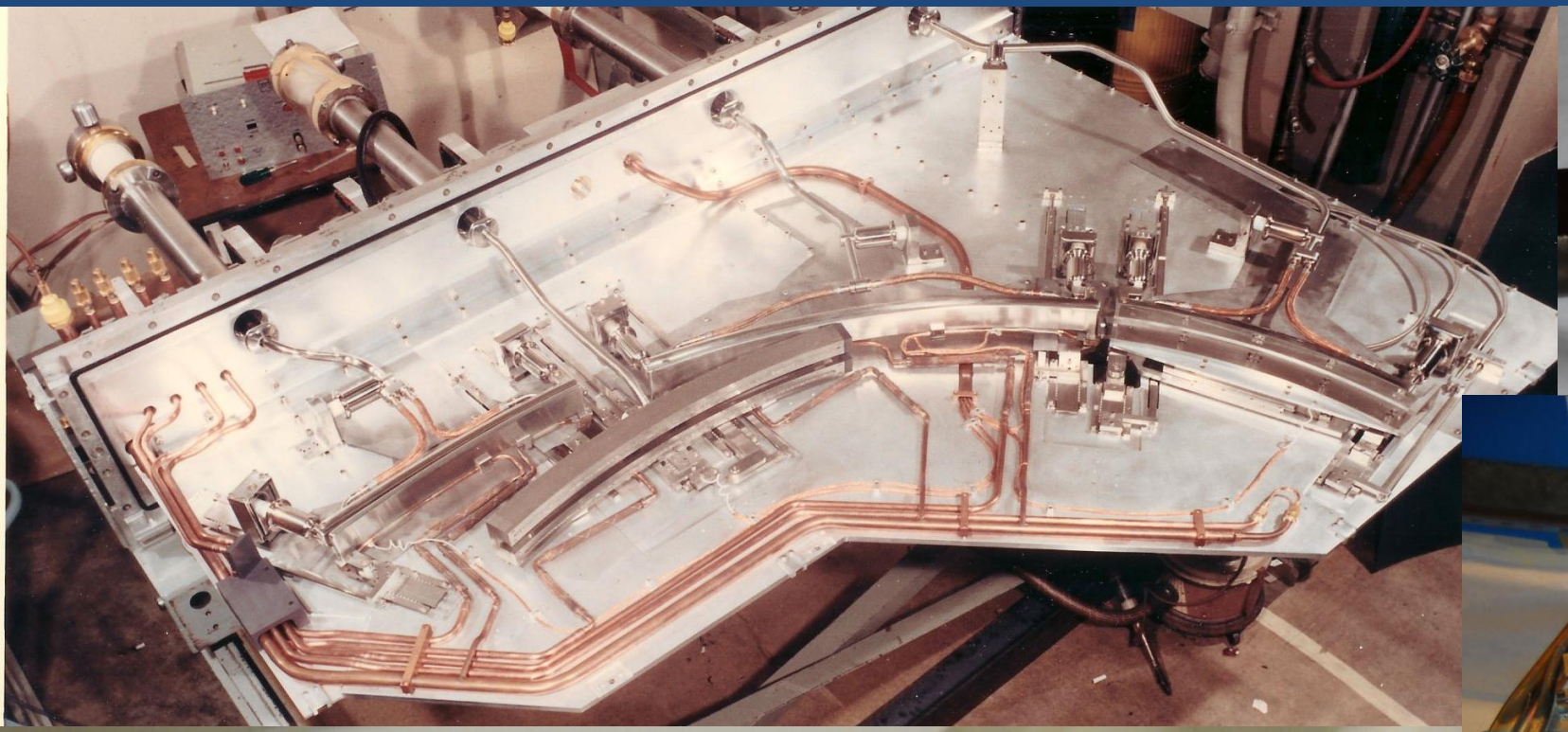


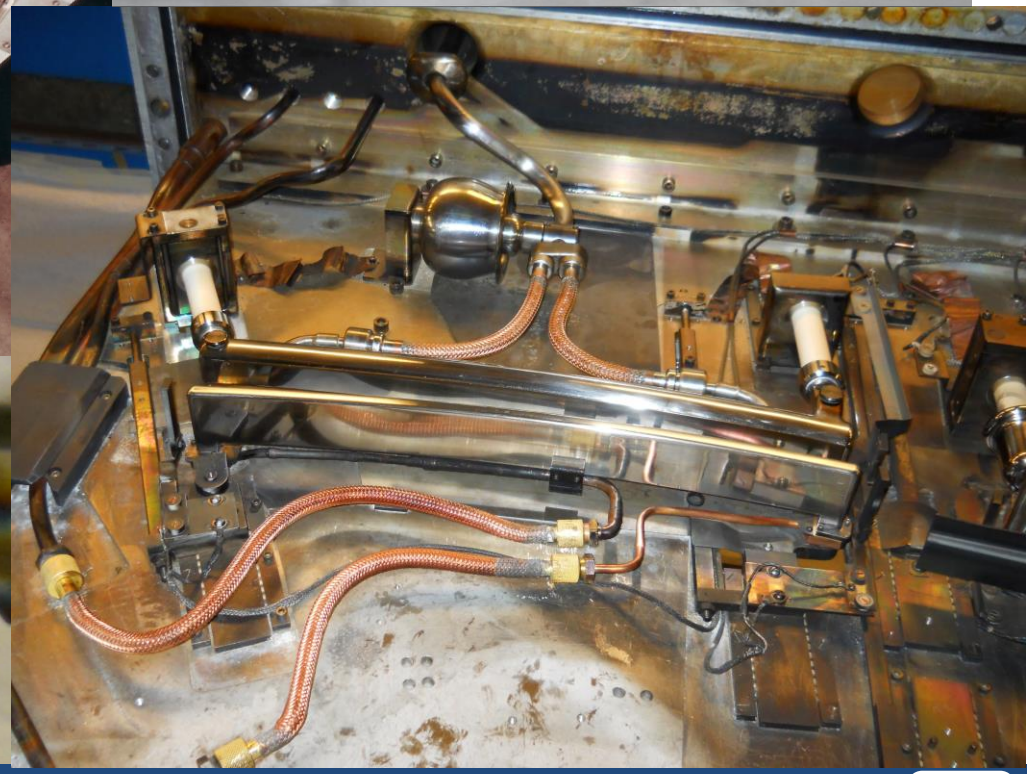
RF System FPA's

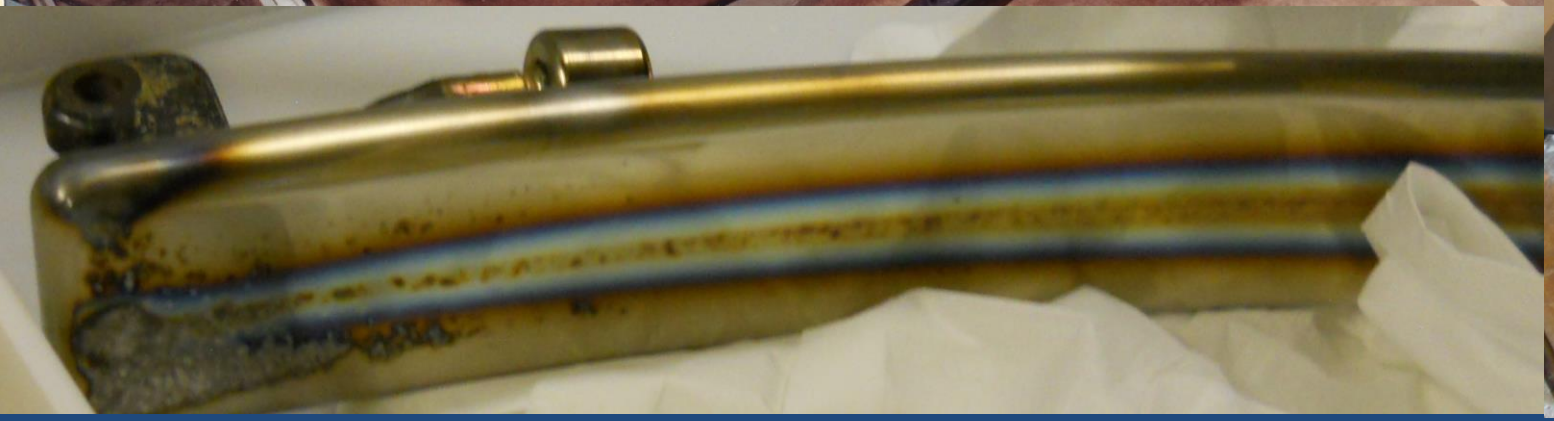
RF System A1000 Drivers

Cooling Tower Replacement

Deflectors







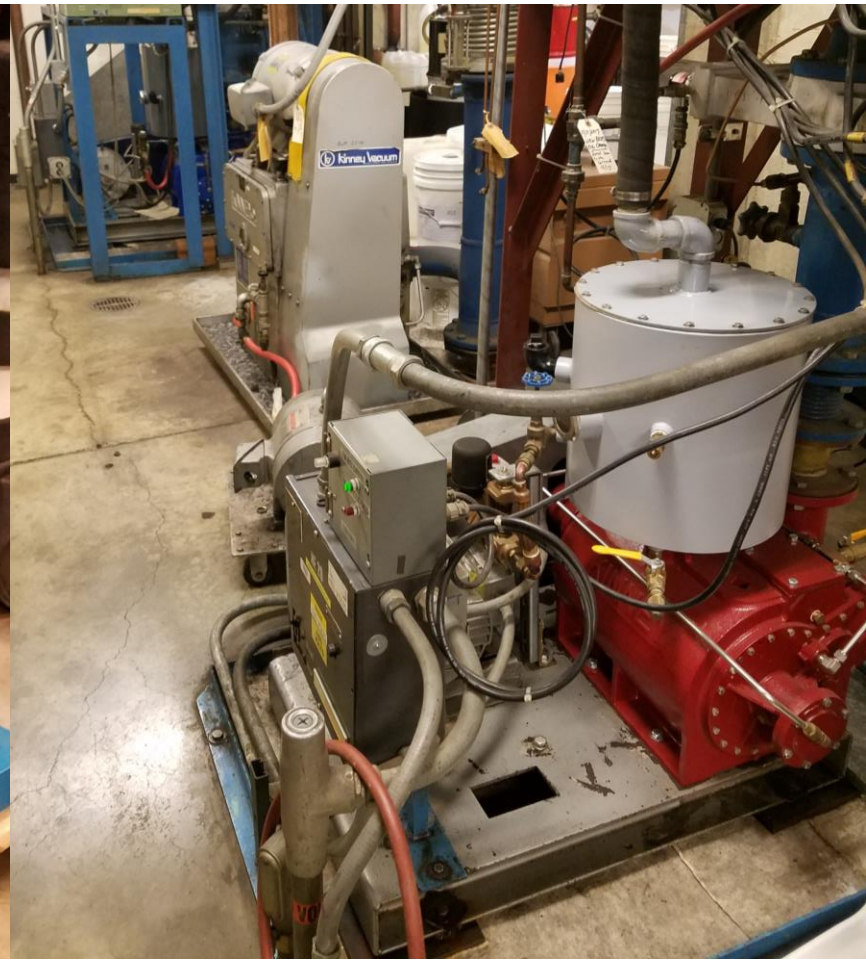
Deflectors (cont.)

Fabricating a second set of deflector extraction electrodes (aluminum vs Inconel)

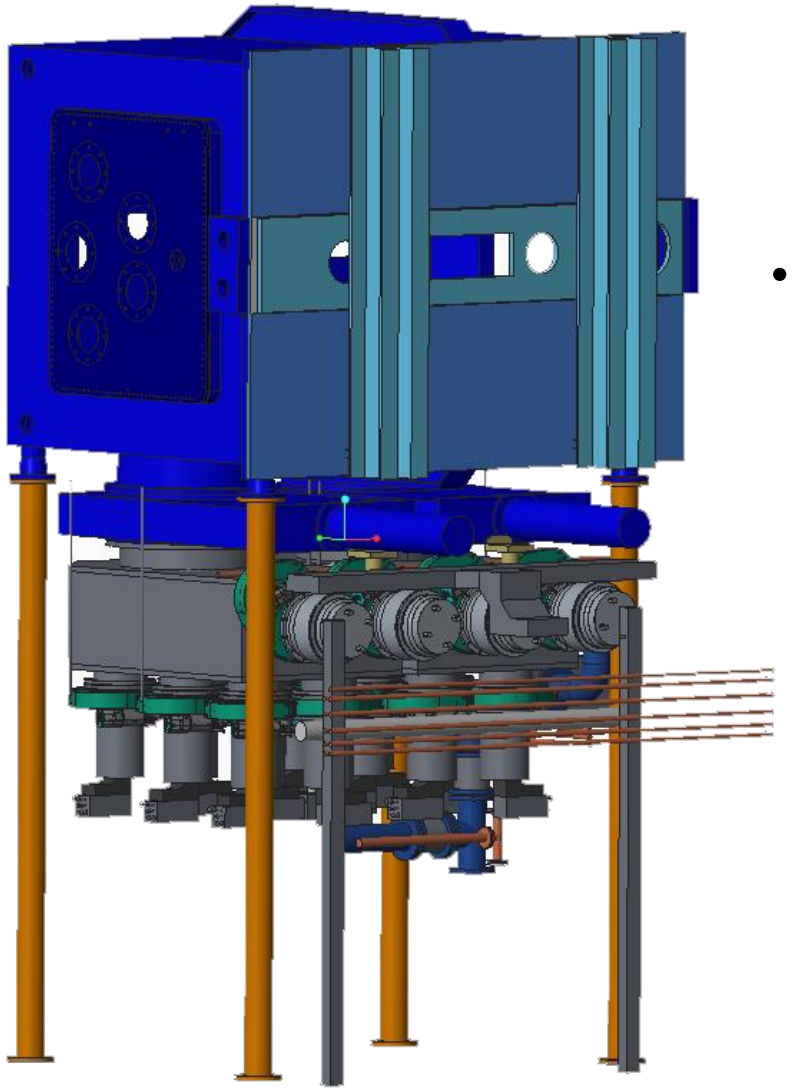
- Should reduce dose rates to maintenance personnel significantly
- Will provide redundancy to a SPOF
- Will significantly shorten duration of standard deflector maintenance during major shutdowns, freeing crew members to focus on other outstanding issues while the facility is down
- Will ease burden on LBNL Radiation Protection Group (RPG)

Other Recent Investments not Mentioned in the Plan

All Cyclotron primary first stage vacuum pumps to be replaced for improved reliability and serviceability

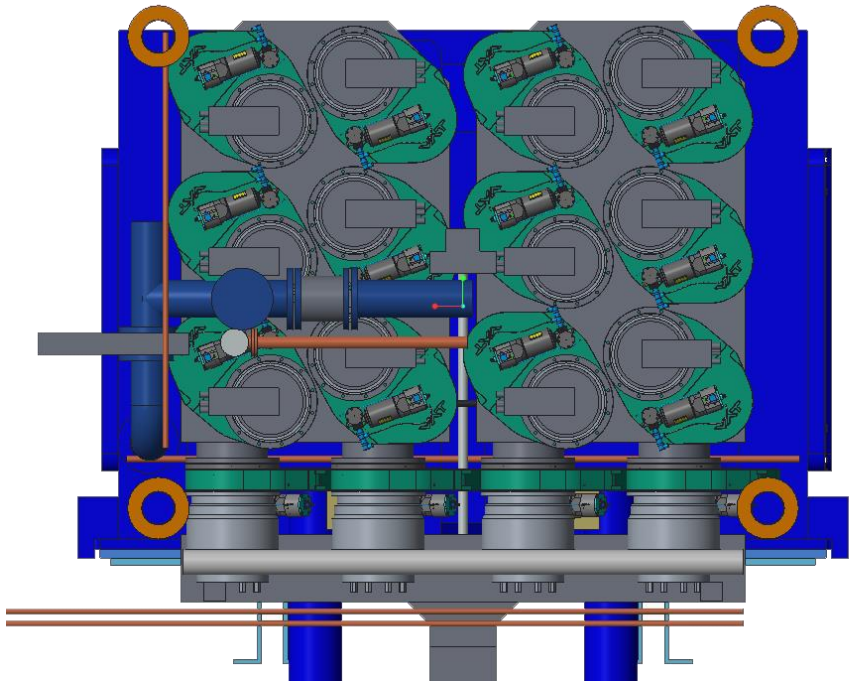


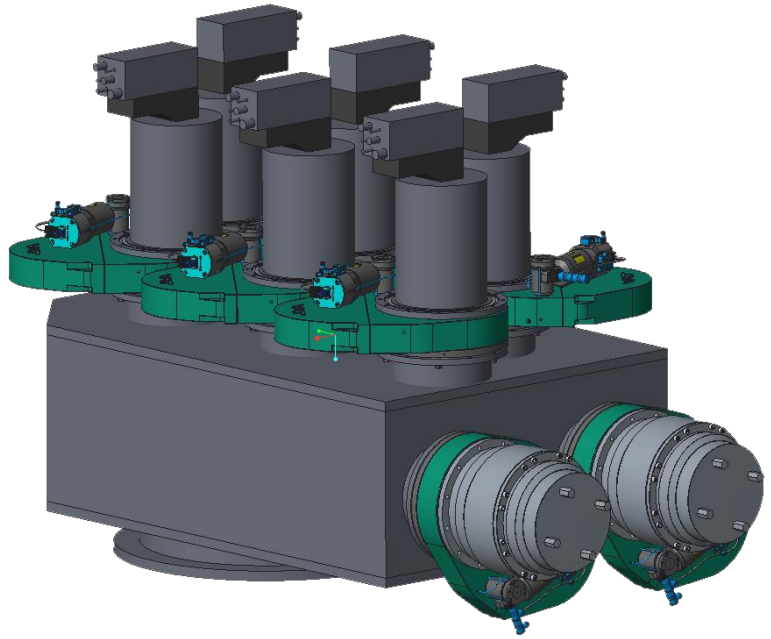
FY21 Plan to Upgrade Cyclotron Pumping



Upgrade to a Cryopump / Turbopump Array

- 2 x 8 Station Pumping Arrays





- Total Pumping per Array – 24,000 & 32,000 l/s
- Increase over DPs of 16,000 – 32,000 l/s total

Conclusion of Presentation

Thank you for your attention

Questions / Comments