Operations Sparing Plan Approach

- A brief presentation at the 7/31/2013 Systems weekly meeting to explain the basic approach for developing a sparing plan for aLIGO operations.
- See also the companion document T1300519, "Sparing Analysis"
- While purchase and maintenance of spares in the aLIGO era is an operations task, definition of the sparing plan is an aLIGO project task.

Sparing Plan

- We need a bottom-up estimate of the spares required for minimal down-time
  - » Budgeting
  - » Logistics/ordering
- Likely that best tool to use is "RAMI" (reliability, availability, maintainability, inspectability) software
  - » Integrates spares list with system reliability model, FMECA model, etc.
  - » Can readily update/maintain sparing analysis input based on experience/data
  - » Can perform more sophisticated failure analysis if/as required
  - » Expensive, requires training & learning curve, etc.
  - » Currently investigating software, e.g. ReliaSoft …
- For now use Excel template (T1300519) to gather inputs

Sparing Plan

- Once each subsystem has provided sparing plan inputs using the Excel template (T1300519) –
  - » An initial spares plan will be published *[aLIGO project scope]*
  - » Consultants will be hired to review the initial reliability (failure/repair rates) for the electronics in an effort to provide better input data to the initial plan *[aLIGO project scope]*
  - » The spares plan & analysis will be improved upon and maintained (including updates for as-experienced failure/repair rates) *[Operations scope]*
- Eventually we will likely migrate from the Excel template to a RAMI software tool *[Operations scope]*

Sparing Analysis Inputs

- LRU = Line-Replaceable Unit (or Lowest Replaceable Unit)
  - » Component, or module, level at which spares are stocked and failed units are repaired and/or replaced
- For each LRU:
  - » Identified by LRU by name & part number
  - » Also define the the next higher level assembly name & part number
  - » Define source or manufacturer
  - » Define replacement cost (hardware/supply/equipment/procurement cost, <u>not</u> labor)
  - » Define repair cost (for most likely repair)
  - » MTBF = Mean Time Between Failure; the mean (average) time between failures (repairable or not) [hrs]
    - – FR = Failure Rate, λ = 1/MTBF [#/hr]
  - » MTBR = Mean Time Between Repairs; the mean (average) time between repairs [hrs]
  - » Quantities
    - – #LRUs required per interferometer
    - – #LRU spares likely to be delivered by aLIGO project to Operations
- Don’t worry about the calculated spares inventory and replenishment rates & costs calculated in the Excel spreadsheet
  - » Systems will review/fix/revise these in the integrated spares plan

Sparing Analysis Input Estimates

- If you don't know, then take a 'best guess' (aka an "engineering estimate")
  - » Better to have some reasonable spares plan base on estimates, than no spares plan due to lack of input!
  - » This applies to failure & repair rates (MTBF and MTTR respectively) as well as quantities
- Use the comment field to identify the source(s) of data and the maturity/reliability of the inputs, e.g.
  - » "MTBF is just a order-of-magnitude estimate"
  - » "Replacement costs is just a ballpark guess"
  - » "Not sure of the surviving number of in-process spares; this is a conservative estimate"
  - » This allows us to track which inputs need more attention/refinement as we improve the plan over time

LIGO

Sparing Plan Example – SUS partial/incomplete

- Create/assemble bill of materials (BOM) for LRUs

	Level	Rack	Rack Desc	Rack #	Chassis	Chassis #	Chassis Qty/rack	LRU	LRU #	LRU Qty/chassis	LRU Qty/rack
2	3						5	Production Monitor Board	D070480	1	5
3	3						5	QUAD and Triple Coil Driver Boards	D0902747	1	5
4	2				Triple Top Coil Driver Chassis Top Assembly	D1001242	5				
5	3						2	AA & AI filter bd	D070081	4	8
6	3						2	ADC AA Interface	D070100	1	2
7	3						2	Chassis Power Regulator PCB	D1000217	1	2
8	2				AA Chassis Top Assembly Drawing (8xDB9 Version)	D0902783	2				
9	3						3	AA & AI filter bd	D070081	2	6
10	3						3	18-bit DAC to Anti-Image Interface Board	D1000551	1	3
11	3						3	Chassis Power Regulator PCB	D1000217	1	3
12	2				18-bit AI Chassis Top Assembly Drawing (4xDB9	D1000305	3				
13	3						6	Production Monitor Board	D070480	1	6
14	3						6	Triple Suspension Acquisiton Coil Driver	D0901047	1	6
15	2				Triple Acquisition Driver Chassis Top Assembly	D090006	6				
16	3						2	Binary Out Interface Board (2 x DB9F, 4 x DB25F)	D1002613	1	2
17	3						2	64 Channel Binary Output Printed Circuit Board	D1001266	1	2
18	2				Binary Output Interface Chassis (DB9 DB25 version) Top Assembly	D1000725	2				
19	3						2	SUS Binary In Interface Board (2xDB9M, 4xDB25M)	D1002628	1	2
20	3						2	64 Channel Binary Input Printed Circuit Board	D1001036	1	2
21	2				Binary Input Interface Chassis (2xDB9M,4x DB25M version) Top Assembly	D1000726	2				
22	1	L1-SUS-C1	HAM3-4	D1200856							
23	3						6	AA Interface Board 2 x 9 Dsub, 2 x 25 Dsub	D10000486	1	6

LIGO

Sparing Plan Example – SUS partial/incomplete

- Use LRU BOM to determine quantities

SUS Rack List

Row Labels
L1-SUS-C1
L1-SUS-C2
L1-SUS-C3
L1-SUS-C4
L1-SUS-C5
L1-SUS-C6
L1-SUS-C7
L1-SUS-C8
L1-SUS-R1
L1-SUS-R2
L1-SUS-R3
L1-SUS-R4
L1-SUS-R5
L1-SUS-R6
L1-SUS-XC1
L1-SUS-XC2
L1-SUS-XR1
L1-SUS-YC1
L1-SUS-YC2
L1-SUS-YR1

SUS Chassis List

Row Labels
18-bit AI Chassis Top Assembly Drawing (4xDB9 Version)
D1000305
AA Chassis Top Assembly Drawing (8xDB9 Version)
D0902783
AA Monitor Chassis Top Assembly (2xDB9 and 2xDB25 version)
D1000721
Binary Input Interface Chassis (2xDB9M,4x DB25M version) Top Assembly
D1000726
Binary Input Interface Chassis (8xDB9 Male Version) Top Assembly
D1001726
Binary Output Interface Chassis (DB9 DB25 version) Top Assembly
D1000725
HAM-A Coil Driver Chassis Top Level Assembly Drawing
D1100687
IO Expansion Chassis - Top Assembly
D1001715
PUM Coil Driver Chassis Top Assembly
D1100303
Quad Top Coil Driver Chassis Top Assembly
D1001782
SUS Binary Out Interface Chassis (8 x DB9 Female version) Top Assembly
D1002593
Triple Acquisition Driver Chassis Top Assembly
D090006
Triple Top Coil Driver Chassis Top Assembly
D1001242
UIM Coil Driver Chassis Top Assembly
D0902668

Count of LRUs from Racks

Row Labels	Sum of LRU
18-bit DAC to Anti-Image Interface Board	**8**
D1000551	8
64 Channel Binary Input Printed Circuit Board	**6**
D1001036	6
64 Channel Binary Output Printed Circuit Board	**6**
D1001266	6
AA & AI filter bd	**92**
D070081	92
AA Interface Board 2 x 9 Dsub, 2 x 25 Dsub	**13**
D10000486	13
ADC	**7**
PCIe-16AI64SSC-64-50M	7
ADC AA Interface	**19**
D070100	19
ADC Adapter boards, 16 bit	**7**
D0902006	7
ADC Adapter boards, 18 bit	**7**
D1000654	7
Binary IO card	**7**
PN DIO-1616L-PE	7
Binary Out Interface Board (2 x DB9F, 4 x DB25F)	**4**
D1002613	4
Binary Out Interface Board (8 x DB9 Female)	**2**
D1001050	2
Chassis Power Regulator PCB	**31**
D1000217	31
Duotone board	**7**
D080335	7
HAM-A Coil Driver	**4**
D1100117	4
Interface backplane	**7**
D0902029	7

Sparing Plan Example – SUS partial/incomplete

- Estimate, or look-up, input parameters for the LRUs

SPARING CALCULATION -- PARTIAL SUS EXAMPLE

#	SubSys	Assembly	LRU Item/Part Name	Part Number (COTS) Drawing Number (custom)	Source/ Manufacturer	Units (board, optic, meter, each, etc.)	COTS (Y/N)	Lead Time (months)	Purchase Price per unit ($)	Repairable? (Y/N)	MTTR (days)	Repair Cost per unit ($)	In Vacuum (Y/N)	Fragility (L/M/H)	Criticality [L/M/H]	MTBF or MTBR (hrs) [1/λ]	Shelf Lifetime (yrs)	Duty Cycle	Qty/ifo [N]	Likely # Project Spares	MANUAL OVERRIDE	# Replenishment Spares per year	Replenishment Cost per year	Factor (N* λ*R)	Actual Confidence	Min # Inventory Req'd	Number to initially purchase	Spares Inventory Cost ($k)	Comments, DCC#s
1	SUS	All suspensions except Aux/SOS	B-OSEM	D060218	U of Birmingham	each	N	9	$1,200	Y	10	$125	Y	L	H	1.39E+06	10	1.00	178	91		1.123	$140	0.277	0.9681	1	0	$0	see MTBF estimate in E1000289-v1, but this is updated with failure data the PD from E1000177-v1 see OSEM count in E1000042-v2, but note that FM qty becomes spares see rough unit costs in M070018-v1 Assume repair is replacement of flexicircuit with PD & LED; assumed s flexicircuit cost as for A-OSEM for repair
2	SUS	All suspensions except BS, OMC, Aux/TT & TMS	A-OSEM	D0901065	LIGO Lab	each	N	9	$600	Y	10	$125	Y	L	H	1.39E+06	10	1.00	108	66		0.681	$85	0.168	0.9874	1	0	$0	see MTBF estimate in E1000289-v1, but this is updated with failure data the PD from E1000177-v1 see OSEM count in E1000042-v2 see rough A-OSEM costs in G0900533-v1
3	SUS	quads	fibers	NA	LIGO Lab	set of 4	N	0.25	$100	N	15	$100	Y	H	H	8.76E+03		1.00	4	4		4.000	$400	0.986	0.9818	3	0	$0	Why don't we have a drawing/part number for the fibers? Where are the dimensional and material specifications defined? long repair time (MTTR), a WAG -- remove lower SUS assy from chamb weld fibers, re-install, pump down and wait for water pressure to get low
4	SUS	see rack BOM for LRU sheet	18-bit DAC to Anti-Image Interface Board	D1000551		bd	N	4	$2,000	Y	5	$100	N	L	H	8.76E+03	10	1.00	8	10		8.000	$800	1.973	0.9844	5	0	$0	engineering estimate on replacement & repair costs. Likely initial spares guess
5	SUS	see rack BOM for LRU sheet	64 Channel Binary Input Printed Circuit Board	D1001036		bd	N	4	$2,000	Y	5	$100	N	L	H	8.76E+03	10	1.00	6	2		6.000	$600	1.479	0.9824	4	2	$4,000	engineering estimate on replacement & repair costs. Likely initial spares guess
6	SUS	see rack BOM for LRU sheet	64 Channel Binary Output Printed Circuit Board	D1001266		bd	N	4	$2,000	Y	5	$100	N	L	H	8.76E+03	10	1.00	6	0		6.000	$600	1.479	0.9824	4	4	$8,000	engineering estimate on replacement & repair costs. Likely initial spares guess
7	SUS	see rack BOM for LRU sheet	AA & AI filter bd	D070081		bd	N	4	$2,000	Y	5	$100	N	L	H	8.76E+03	10	1.00	92	10		92.000	$9,200	22.68	0.9625	31	21	$42,000	engineering estimate on replacement & repair costs. Likely initial spares guess
8	SUS	see rack BOM for LRU sheet	AA Interface Board 2 x 9 Dsub, 2 x 25 Dsub	D10000486		bd	N	4	$2,000	Y	5	$100	N	L	H	8.76E+03	10	1.00	13	5		13.000	$1,300	3.205	0.9550	6	1	$2,000	engineering estimate on replacement & repair costs. Likely initial spares guess
6	SUS	see rack BOM for LRU sheet	ADC	PCIe-16AI64SSC-64-5	LIGO Lab	bd	N	4	$2,000	Y	5	$100	N	L	H	8.76E+03	10	1.00	7	3		7.000	$700	1.726	0.9687	4	1	$2,000	engineering estimate on replacement & repair costs. Likely initial spares
7	SUS	see rack BOM for LRU sheet	ADC AA Interface	D070100	LIGO Lab	bd	N	4	$2,000	Y	5	$100	N	L	H	8.76E+03	10	1.00	19	5		19.000	$1,900	4.685	0.9505	8	3	$6,000	engineering estimate on replacement & repair costs. Likely initial spares