How to Run Three Telescopes with Two People

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New Mexico Symposium 2017

OVERVIEW

- Operation of an Long Wavelength Array Station
  - Manual vs. automated
- The Swarm Concept
- eLWA as a Swarm Telescope
- Implications for the operation of ngVLA

LWA1 OPERATIONS

- People, e-mails, text files, and spreadsheets

Date	LWA Operator on Duty Person
Mar27-Apr9	Joe C.
Apr10-23	Frank S.
Apr23-30	Jayce D.
May1-7	Greg T.

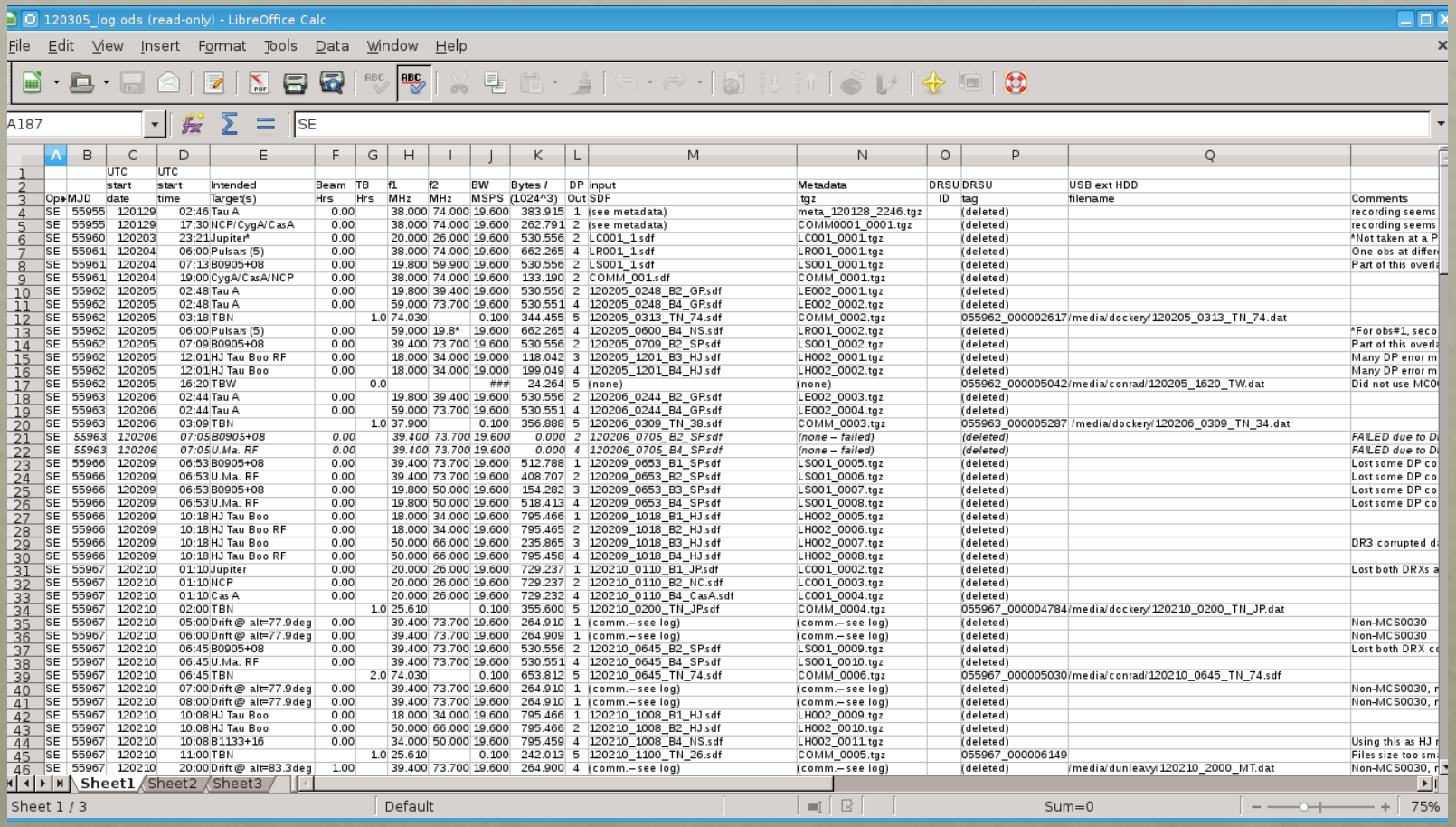
```
**************
* MJD 56533
**************
17:10 Local time 08/29/30 PASI Crashed

20:39 Local time 8/29/30 Station Shutdown wait for manuel reset


at 00:05 08/30/13 -f ./INIdp.sh
job 974 at Fri Aug 30 00:05:00 2013

LS003_130830_0618_320_B1.sdf
LS003_130830_0618_321_B2.sdf
LS003_130830_0618_322_B3.sdf
LS003_130830_0618_323_B4.sdf
Did not observe
```

LWA1 OPERATIONS



120305_log.ods (read-only) - LibreOffice Calc

File Edit View Insert Format Tools Data Window Help

A187 | SE

	Op	MJD	UTC start date	UTC start time	Intended Target(s)	Beam Hrs	TB Hrs	f1 MHz	f2 MHz	BW MSPS	Bytes / (1024^3)	DP Out	input SDF	Metadata .tgz	DRSU ID	DRSU tag	USB ext HDD filename	Comments
4	SE	55955	120129	02:46	Tau A	0.00		38.000	74.000	19.600	383.915	1	(see metadata)	meta_120128_2246.tgz		(deleted)		recording seems
5	SE	55955	120129	17:30	NCP/CygA/CasA	0.00		38.000	74.000	19.600	262.791	2	(see metadata)	COMM0001_0001.tgz		(deleted)		recording seems
6	SE	55960	120203	23:21	Jupiter*	0.00		20.000	26.000	19.600	530.556	2	LC001_1.sdf	LC001_0001.tgz		(deleted)		*Not taken at a P
7	SE	55961	120204	06:00	Pulsars (5)	0.00		38.000	74.000	19.600	662.265	4	LR001_1.sdf	LR001_0001.tgz		(deleted)		One obs at differ
8	SE	55961	120204	07:13	B0905+08	0.00		19.800	59.900	19.600	530.556	2	LS001_1.sdf	LS001_0001.tgz		(deleted)		Part of this overl
9	SE	55961	120204	19:00	CygA/CasA/NCP	0.00		38.000	74.000	19.600	133.190	2	COMM_001.sdf	COMM_0001.tgz		(deleted)		
10	SE	55962	120205	02:48	Tau A	0.00		19.800	39.400	19.600	530.556	2	120205_0248_B2_GP.sdf	LE002_0001.tgz		(deleted)		
11	SE	55962	120205	02:48	Tau A	0.00		59.000	73.700	19.600	530.551	4	120205_0248_B4_GP.sdf	LE002_0002.tgz		(deleted)		
12	SE	55962	120205	03:18	TBN		1.0	74.030		0.100	344.455	5	120205_0313_TN_74.sdf	COMM_0002.tgz		055962_000002617	/media/dockery/120205_0313_TN_74.dat	
13	SE	55962	120205	06:00	Pulsars (5)	0.00		59.000	19.8*	19.600	662.265	4	120205_0600_B4_NS.sdf	LR001_0002.tgz		(deleted)		*For obs#1, seco
14	SE	55962	120205	07:09	B0905+08	0.00		39.400	73.700	19.600	530.556	2	120205_0709_B2_SP.sdf	LS001_0002.tgz		(deleted)		Part of this overl
15	SE	55962	120205	12:01	HJ Tau Boo RF	0.00		18.000	34.000	19.000	118.042	3	120205_1201_B3_HJ.sdf	LH002_0001.tgz		(deleted)		Many DP error m
16	SE	55962	120205	12:01	HJ Tau Boo	0.00		18.000	34.000	19.000	199.049	4	120205_1201_B4_HJ.sdf	LH002_0002.tgz		(deleted)		Many DP error m
17	SE	55962	120205	16:20	TBW		0.0			###	24.264	5	(none)	(none)		055962_000005042	/media/conrad/120205_1620_TW.dat	Did not use MC0
18	SE	55963	120206	02:44	Tau A	0.00		19.800	39.400	19.600	530.556	2	120206_0244_B2_GP.sdf	LE002_0003.tgz		(deleted)		
19	SE	55963	120206	02:44	Tau A	0.00		59.000	73.700	19.600	530.551	4	120206_0244_B4_GP.sdf	LE002_0004.tgz		(deleted)		
20	SE	55963	120206	03:09	TBN		1.0	37.900		0.100	356.888	5	120206_0309_TN_38.sdf	COMM_0003.tgz		055963_000005287	/media/dockery/120206_0309_TN_34.dat	
21	SE	*55963*	*120206*	*07:05*	*B0905+08*	*0.00*		*39.400*	*73.700*	*19.600*	*0.000*	*2*	*120206_0705_B2_SP.sdf*	*(none – failed)*		*(deleted)*		*FAILED due to D*
22	SE	*55963*	*120206*	*07:05*	*U.Ma. RF*	*0.00*		*39.400*	*73.700*	*19.600*	*0.000*	*4*	*120206_0705_B4_SP.sdf*	*(none – failed)*		*(deleted)*		*FAILED due to D*
23	SE	55966	120209	06:53	B0905+08	0.00		39.400	73.700	19.600	512.788	1	120209_0653_B1_SP.sdf	LS001_0005.tgz		(deleted)		Lost some DP co
24	SE	55966	120209	06:53	U.Ma. RF	0.00		39.400	73.700	19.600	408.707	2	120209_0653_B2_SP.sdf	LS001_0006.tgz		(deleted)		Lost some DP co
25	SE	55966	120209	06:53	B0905+08	0.00		19.800	50.000	19.600	154.282	3	120209_0653_B3_SP.sdf	LS001_0007.tgz		(deleted)		Lost some DP co
26	SE	55966	120209	06:53	U.Ma. RF	0.00		19.800	50.000	19.600	518.413	4	120209_0653_B4_SP.sdf	LS001_0008.tgz		(deleted)		Lost some DP co
27	SE	55966	120209	10:18	HJ Tau Boo	0.00		18.000	34.000	19.600	795.466	1	120209_1018_B1_HJ.sdf	LH002_0005.tgz		(deleted)		
28	SE	55966	120209	10:18	HJ Tau Boo RF	0.00		18.000	34.000	19.600	795.465	2	120209_1018_B2_HJ.sdf	LH002_0006.tgz		(deleted)		
29	SE	55966	120209	10:18	HJ Tau Boo	0.00		50.000	66.000	19.600	235.865	3	120209_1018_B3_HJ.sdf	LH002_0007.tgz		(deleted)		DR3 corrupted d
30	SE	55966	120209	10:18	HJ Tau Boo RF	0.00		50.000	66.000	19.600	795.458	4	120209_1018_B4_HJ.sdf	LH002_0008.tgz		(deleted)		
31	SE	55967	120210	01:10	Jupiter	0.00		20.000	26.000	19.600	729.237	1	120210_0110_B1_JP.sdf	LC001_0002.tgz		(deleted)		Lost both DRXs a
32	SE	55967	120210	01:10	NCP	0.00		20.000	26.000	19.600	729.237	2	120210_0110_B2_NC.sdf	LC001_0003.tgz		(deleted)		
33	SE	55967	120210	01:10	Cas A	0.00		20.000	26.000	19.600	729.232	4	120210_0110_B4_CasA.sdf	LC001_0004.tgz		(deleted)		
34	SE	55967	120210	02:00	TBN		1.0	25.610		0.100	355.600	5	120210_0200_TN_JP.sdf	COMM_0004.tgz		055967_000004784	/media/dockery/120210_0200_TN_JP.dat	
35	SE	55967	120210	05:00	Drift @ alt=77.9deg	0.00		39.400	73.700	19.600	264.910	1	(comm.– see log)	(comm.– see log)		(deleted)		Non-MCS0030
36	SE	55967	120210	06:00	Drift @ alt=77.9deg	0.00		39.400	73.700	19.600	264.909	1	(comm.– see log)	(comm.– see log)		(deleted)		Non-MCS0030
37	SE	55967	120210	06:45	B0905+08	0.00		39.400	73.700	19.600	530.556	2	120210_0645_B2_SP.sdf	LS001_0009.tgz		(deleted)		Lost both DRX c
38	SE	55967	120210	06:45	U.Ma. RF	0.00		39.400	73.700	19.600	530.551	4	120210_0645_B4_SP.sdf	LS001_0010.tgz		(deleted)		
39	SE	55967	120210	06:45	TBN		2.0	74.030		0.100	653.812	5	120210_0645_TN_74.sdf	COMM_0006.tgz		055967_000005030	/media/conrad/120210_0645_TN_74.sdf	
40	SE	55967	120210	07:00	Drift @ alt=77.9deg	0.00		39.400	73.700	19.600	264.910	1	(comm.– see log)	(comm.– see log)		(deleted)		Non-MCS0030, r
41	SE	55967	120210	08:00	Drift @ alt=77.9deg	0.00		39.400	73.700	19.600	264.910	1	(comm.– see log)	(comm.– see log)		(deleted)		Non-MCS0030, r
42	SE	55967	120210	10:08	HJ Tau Boo	0.00		18.000	34.000	19.600	795.466	1	120210_1008_B1_HJ.sdf	LH002_0009.tgz		(deleted)		
43	SE	55967	120210	10:08	HJ Tau Boo	0.00		50.000	66.000	19.600	795.466	2	120210_1008_B2_HJ.sdf	LH002_0010.tgz		(deleted)		
44	SE	55967	120210	10:08	B1133+16	0.00		34.000	50.000	19.600	795.459	4	120210_1008_B4_NS.sdf	LH002_0011.tgz		(deleted)		Using this as HJ r
45	SE	55967	120210	11:00	TBN		1.0	25.610		0.100	242.013	5	120210_1100_TN_26.sdf	COMM_0005.tgz		055967_000006149		Files size too sm
46	SE	55967	120210	20:00	Drift @ alt=83.3deg	1.00		39.400	73.700	19.600	264.900	4	(comm.– see log)	(comm.– see log)		(deleted)	/media/dunleavy/120210_2000_MT.dat	Non-MCS0030, r

Sheet1 Sheet2 Sheet3

Sheet 1 / 3 | Default | Sum=0 | 75%

LWA1 OPERATIONS

- The manual approach worked ~~well~~ ok for many years
- Biggest problems were:
  - Sending the spreadsheet around caused occasional versioning problems
  - Manual entry of all values allows for typos.
  - Response time to problems was slow
    - Environmental conditions, system problems, etc.
    - This made things like triggered observations difficult to impossible

RISE OF THE MACHINE

THE HAL SYSTEM

From lwa.station.1@gmail.com

Subject **Schedule for UTC 2017/10/29 - HAL**

To lwa1ops@phys.unm.edu

Reply Rep

```
HAL has successfully created the following schedule for UTC 2017/10/29:

Auto-Deconflict and Balance Move List:
  * [B] Moving COMJD, 110 from beam 2 to 4
  * [B] Moving COMJD, 111 from beam 2 to 4
  * [B] Moving COMJD, 112 from beam 2 to 4
  * [B] Moving COMJD, 115 from beam 2 to 3
  * [B] Moving COMJD, 117 from beam 2 to 4
  * [B] Moving COMJD, 116 from beam 2 to 3
  * [B] Moving COMJD, 118 from beam 2 to 4
  * [B] Moving COMJD, 120 from beam 2 to 3
  * [B] Moving COMJD, 121 from beam 2 to 4

Schedule:
  * 2017/10/29 00:16:00 /home/op1/MCS/sch/INIdp.sh (#33951)
  * 2017/10/29 00:36:56 COMJD, session 110 starts on beam 4
  * 2017/10/29 00:43:54 COMJD, session 110 stops on beam 4
  * 2017/10/29 01:04:00 /home/op1/MCS/sch/startTBN_split.sh (#33962)
  * 2017/10/29 01:08:00 /home/op1/MCS/exec/acquireTBWAndProcess.py (#33963)
  * 2017/10/29 01:23:00 /home/op1/MCS/sch/operatorScripts/selectBestDRSU.py --all (#33964)
  * 2017/10/29 01:25:00 /home/op1/MCS/sch/operatorScripts/postDRSUStatus.py (#33965)
  * 2017/10/29 01:51:00 /home/op1/MCS/sch/INIdp.sh (#33952)
  * 2017/10/29 02:11:58 COMJD, session 111 starts on beam 4
  * 2017/10/29 02:18:56 COMJD, session 111 stops on beam 4
```

THE HAL SYSTEM

From lwa.station.1@gmail.com

Reply

Subject **Remote Trigger - HAL is taking control of the station**

To lwa1ops@phys.unm.edu

Cc Kevin Stovall, Jayce Dowell

```
HAL is taking control of LWA1 in order to observe the GRB trigger 'Fermi_GBM_GRB #53135660
Observations will start at 2017-11-02 23:05:30 (0:02:12.719986 after the event) and contin

The following entries the MCS/exec queue have been canceled:
  * LS006, session 5876
  * LS006, session 5861
  * LS006, session 5875
  * LS006, session 5862

The following DR operations have been canceled:
  * 058059_000930183 on DR2
  * 058059_000930182 on DR3

The following 'at' commands have been canceled:
  * 34079
  * 34097
  * 34103
```

THE SWARM TELESCOPE

- The swarm concept was developed as a way to control a distributed array under the constraint that each element is independently operated
  - LWA a stations owned and operated by different universities
  - Each stations would have its own set of science and idle time would be used to synthesize a larger array
- Two parts for this:
  - HAL as a way to manage the stations and respond to triggers
  - SmartCopy as a way to deal with the data in a non-conflicting way

A SWARM OF DIPOLE ARRAYS

- The swarm concept is what powers the current eLWA system
- VLA 4-band sessions trigger LWA1 and LWA-SV so that they can follow along
  - HAL/SAL deal with the scheduling and interrupting observations in order to follow along
  - SmartCopy deals with aggregating the LWA data for offline correlation
- System can be expanded with other stations or to support other modes (meteor, solar, etc.)

A SWARM OF DISHES

- The swarm concept may also be of interest to ngVLA
  - Large of number of elements over a wide area
  - Need to be happy with 90%
  - Weather or other environmental conditions will be different across the array
  - Observations will need to be able to use what is good and ignore the rest
- This can also be used to create new behavior in the array
  - Think self organizing beam formed clusters for VLBA tie-ins

A SWARM OF DISHES

- The swarm concept also impacts other areas of operations
  - Smart telescope control requires strong coupling of the software and the hardware
    - Predictive failure analysis possible through data mining which can be used to improve the software
  - Dynamic allocation of resources means that many projects may run at once with sub-arrays
    - Time allocation may be dynamic with dishes x time under some baseline distribution constraint
  - Possibility to optimize other variables in operation, i.e., data transport or correlator load

AUTOMATION ADVANTAGES

- Automation is key to operating multi-element arrays under constraints of availability, reliability, and efficiency
  - Provides 24/7 monitoring and response to a variety of conditions
  - Helps reduce the load on people so that can focus on what automation is not good at
- NRAO and ngVLA can benefit from the swarm concept of control and operations

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