## VLA-GOLDSTONE ARRAY FORMAL REVIEW



**JULY 1987** 

# VLA-GOLDSTONE ARRAY AGENDA



TOPIC	PRESENTER	TIME
• INTRODUCTION	P.T. WESTMORELAND/ R.D. EKERS/ R. STEVENS	9:00
• BACKGROUND	J.W. LAYLAND	9:15
• VGTA PROJECT INTRODUCTION	D.W. BROWN	10:00
• IMPLEMENTATION PLAN	K.P. BARTOS	10:15
• SYSTEM DESIGN ISSUES	D.W. BROWN	10:45
• LUNCH		12:15
• NRAO IMPLEMENTATION	W.D. BRUNDAGE	1:00
• IMPLEMENTATION STATUS	K.P. BARTOS	2:30
• OPERATIONS PLANNING	L.E. BUTCHER	3:18
• VGTA PROJECT REMARKS	D.W. BROWN/R.A. SRAMEK	3:4
BOARD DISCUSSION	R. STEVENS	4:00

# VLA-GOLDSTONE ARRAY FORMAL REVIEW

INTRODUCTION



P.T. WESTMORELAND R.D. EKERS R. STEVENS

**JULY 1987** 

# INTRODUCTION REVIEW BOARD



• P.T. WESTMORELAND	JPL, CONVENING AUTHORITY
• R. STEVENS	JPL, CHAIRMAN
• D.P. HOLMES	JPL, SECRETARY
• R.D. EKERS	NRAO, DEPUTY DIRECTOR, VLA SITE
• P.J. NAPIER	NRAO, VLB ARRAY PROJECT MANAGE
• R.P. MATHISON	JPL, DIVISION 33
• T.H. THORNTON	JPL, DIVISION 36
• J.W. LAYLAND	JPL, OFFICE 410
• G.M. RESCH	JPL, OFFICE 420
• R.J. AMOROSE	JPL, OFFICE 440
• N.R. HAYNES	VOYAGER PROJECT MANAGER

PTW-1 7-8-87

# VLA-GOLDSTONE ARRAY FORMAL REVIEW

**BACKGROUND** 



J.W. LAYLAND

**JULY 1987** 

## BACKGROUND AGENDA





- VOYAGER HELIOCENTRIC TRAJECTORY
- JPL (VOYAGER) "REQUIREMENTS"
- VOYAGER LINK PERFORMANCE AT NEPTUNE 1984 ESTIMATE
- NRAO VLA "REQUIREMENTS" / STATUS IN 1987
- SYSTEM DESIGN ISSUES (AS OF 1984)
- NOTES ON VLA PLANNING 1984
- CONCLUSION OF 1984 FORMAL REVIEW

## **BACKGROUND**

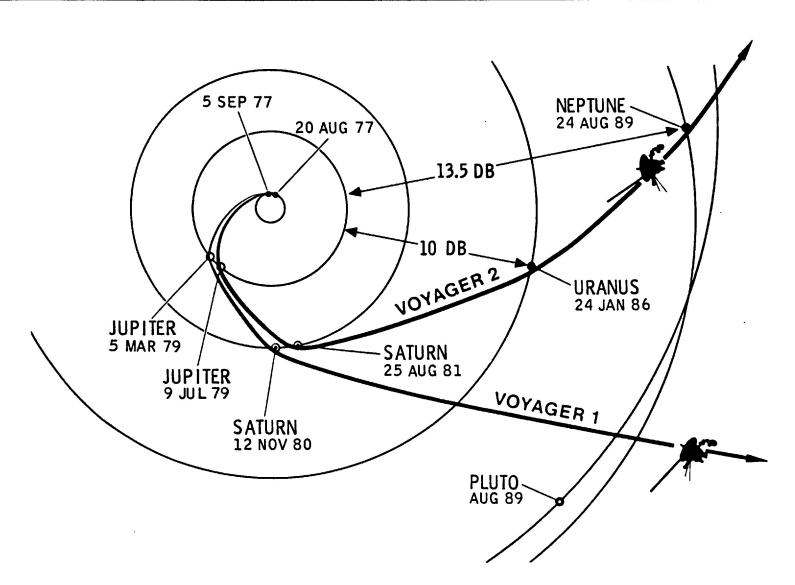
## SIGNIFICANT EVENTS IN DSN TELEMETRY ARRAYING



1972	• ARRAY DEMONSTRATION AT DSS 61/63 WITH PIONEER 8	
1974	• ARRAY DEMONSTRATION AT DSS 12/13/14 WITH MVM	
1977	• LAUNCH OF VOYAGER TO JUPITER/SATURN WITH URANUS/NEPTUNE OPTION	
1980 MAY • INITIAL LETTER TO CSIRO/PARKES		
1980/81 • ARRAY OPERATIONS 64 M/34 M FOR VOYAGER AT SATURN		
1982 FEB	• INITIAL JPL LETTER TO NRAO CONCERNING VLA	
MARCH	• REVIEW OF PARKES PHASE A STUDY	
1983 JULY	• WEAK-SIGNAL TESTS OF AUTO-PHASING AT VLA	
1984 JUNE	• FORMAL REVIEW OF VLA ARRAYING	
1984 DEC	• FIRST VLA X-BAND TESTS	
1986 JAN	• ARRAY OPERATIONS 64/34/34 + PARKES FOR VOYAGER-URANUS	
1986 JUNE	• FIRST VLA X-BAND AUTO-PHASING TESTS ON VOYAGER	
1987 APRIL	• FIRST VLA-VOYAGER TELEMETRY DETECTION AND RECORDING	

# BACKGROUND VOYAGER HELIOCENTRIC TRAJECTORY





6485-3462b

\_JPL

**VLA-GOLDSTONE ARRAY FORMAL REVIEW** 

JWL-2 JWL-3 6-22-84 7-8-87

## **BACKGROUND**

### JPL (VOYAGER) "REQUIREMENTS"



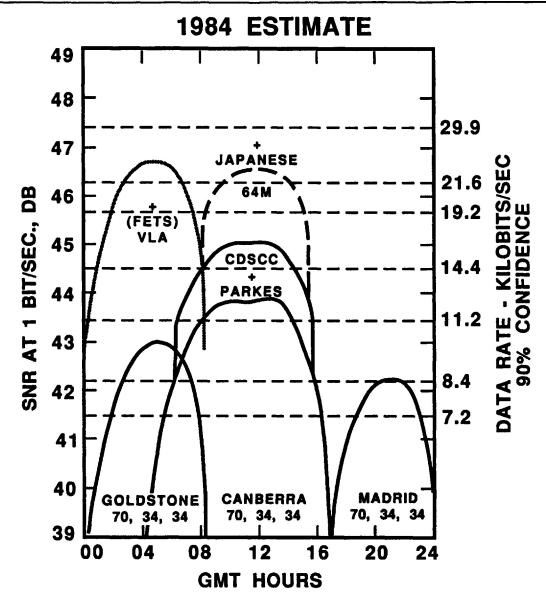
- VLA RECEPTION CAPABILITY AT 8.4 GHz EQUIVALENT TO 2.5 TIMES A DSN 64-METER
- VOYAGER-NEPTUNE IMAGING SCIENCE OBSERVATIONS INCREASED BY 35-50% OVER BASELINE (DSN + PARKES)\*
  - VLA-GDSCC ARRAYED SUPPORT FOR 21.6 KBPS AT NEPTUNE ENCOUNTER
  - VLA-GDSCC ARRAYED SUPPORT FOR 40 PASSES AT NEPTUNE ENCOUNTER

\*DEPENDS UPON SPACECRAFT CONDITION

## **BACKGROUND**

## **VOYAGER LINK PERFORMANCE AT NEPTUNE**





6485-3464b

**JPL** 

**VLA-GOLDSTONE ARRAY FORMAL REVIEW** 

JWL-4A 6-22-87

JWL-5 7-8-87

# BACKGROUND NRAO-VLA "REQUIREMENTS"



- SPECTACULAR VOYAGER PLANETARY ASTRONOMY AT NEPTUNE
- A USABLE AND USEFUL 8.0-8.8 GHz RECEPTION CAPABILITY ON ALL VLA ANTENNAS
  - RADAR ASTRONOMY WITH DSN-GOLDSTONE
  - RADIO ASTRONOMY -- ADDITIONAL SAMPLE FREQUENCY FOR SPECTRAL MONITORING

JWL-5 6-22-84

### STATUS IN 1987

- FIRST 8-GHz VLBI EXPERIMENTS JULY 1986/MAY 1987
- FIRST GOLDSTONE-VLA SOLAR SYSTEM RADAR MAY 1987

## BACKGROUND SYSTEM DESIGN ISSUES

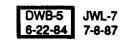


### **ISSUES TO BE ADDRESSED IN FY 85**

- SYSTEMATIC PROBLEMS (E.G. RAO COMBINING, 1.6 MS DATA GAPS)
- POSSIBLE USE OF HEMT TECHNOLOGY vs CURRENT FET BASELINE FOR LNA
- SYMBOL STREAM COMBINING AT GDSCC VS BASEBAND BASELINE

### **ISSUES TO BE ADDRESSED IN FY 86**

- POSSIBLE REQUIREMENT FOR ADDITIONAL POWER GENERATION CAPACITY AT VLA
- REAL-TIME VS NEAR-REAL-TIME COMBINING VS BOTH

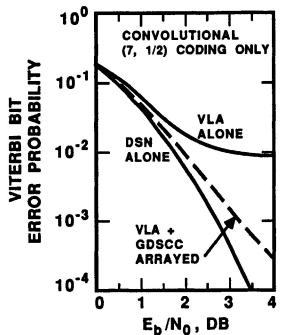


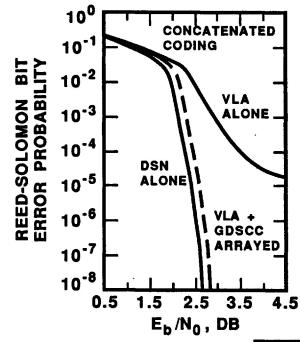
### BACKGROUND

### **NOTES ON VLA PLANNING - 1984**



- COMBINER USES 3-LEVEL QUANTIZATION--SNR DEGRADATION APPROX 1 DB
  - ALREADY INCLUDED IN TELECOM CURVES
- VLA SIGNAL TRANSMISSION INTERRUPTED FOR 1.6 MS EACH 52 MS FOR SYSTEM **CONTROL PURPOSES** 
  - EFFECT ON PHASE-LOCK AND DETECTION ASSUMED NEGLIGIBLE
    - -- NEEDS TO BE VERIFIED --
  - EFFECT ON CODED DATA IS USAGE DEPENDANT:
    - ERRORS IF VLA USED ALONE
    - DEGRADATION OF UP TO 0.3 DB IF VLA ARRAYED WITH GOLDSTONE





3-29-84

JWL-8 7-8-87

## **BACKGROUND**

### **CONCLUSION OF 1984 FORMAL REVIEW**



- ARRAYING OF THE VLA WITH GDSCC FOR SUPPORT OF THE VOYAGER AT NEPTUNE PROVIDES A SUBSTANTIAL INCREMENT TO THE DATA RETURNED
- OVERALL COST TO NASA IS ABOUT \$17 M
- ADEQUATE CONFIDENCE EXISTS TO PROCEED WITH ENGINEERING DEVELOPMENT OF THE VLA X-BAND CAPABILITY
- PLANNED TESTS AND ANALYSIS WILL ESTABLISH FULL NEEDED CONFIDENCE BEFORE LARGE EXPENDITURE OF IMPLEMENTATION RESOURCES

## BACKGROUND 1984 FORMAL REVIEW RFA STATUS



- NINE REQUESTS FOR ACTION SUBMITTED
  - FIVE ADVISORY FOR DEVELOPMENT OF MANAGEMENT PLAN OR FOR SYSTEM ENGINEERING/DESIGN
  - FOUR SPECIFIED ACTION ITEMS
    - NO. 4: REAL-TIME REQUIREMENT FROM VOYAGER
    - NO. 5: LINK DESIGN CONTROL UNCERTAINTY
    - NO. 8: SCIENCE REQUIREMENTS
    - NO. 9: NRAO COST PROFILE
- ALL ITEMS CLOSED (WITH BOARD CONCURRENCE) BY OCTOBER 3, 1984

### **BACKGROUND**

## VLA ARRAYING FORMAL REVIEW, JUNE 22, 1984



### REVIEW BOARD MEMBERSHIP

- R. STEVENS, CHAIRMAN
- R.J. AMOROSE
- M.J. CHAHINE
- R.D. EKERS
- W.E. GIBERSON (G.P. TEXTOR)
- R.K. MALLIS
- R.P. MATHISON
- P.J. NAPIER
- C.H. STEMBRIDGE
- P.T. WESTMORELAND
- R.E. McKEE, SECRETARY

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# VLA-GOLDSTONE ARRAY FORMAL REVIEW

VGTA PROJECT INTRODUCTION

JPL

D.W. BROWN

**JULY 1987** 

## VGTA PROJECT INTRODUCTION



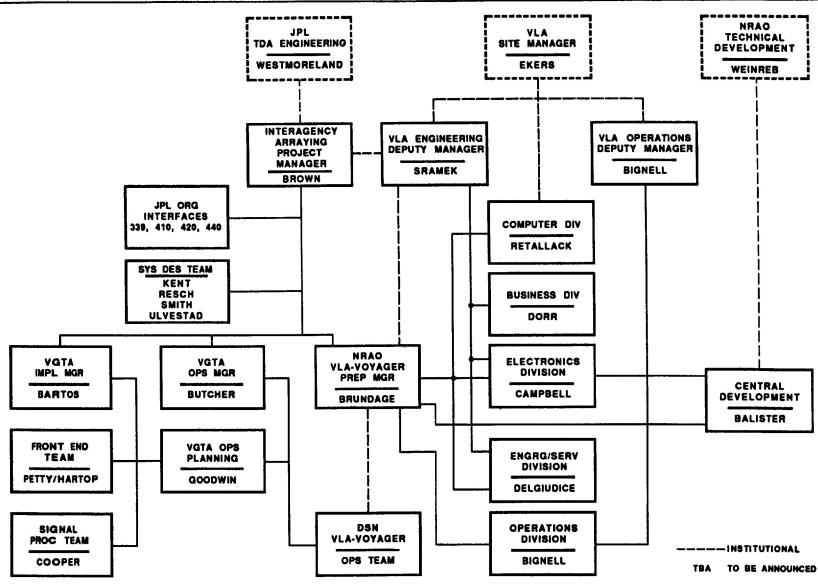


- PROJECT ORGANIZATION
- SYSTEM BLOCK DIAGRAM
- VLA SITE AERIAL VIEW

## VGTA PROJECT INTRODUCTION

### PROJECT ORGANIZATION

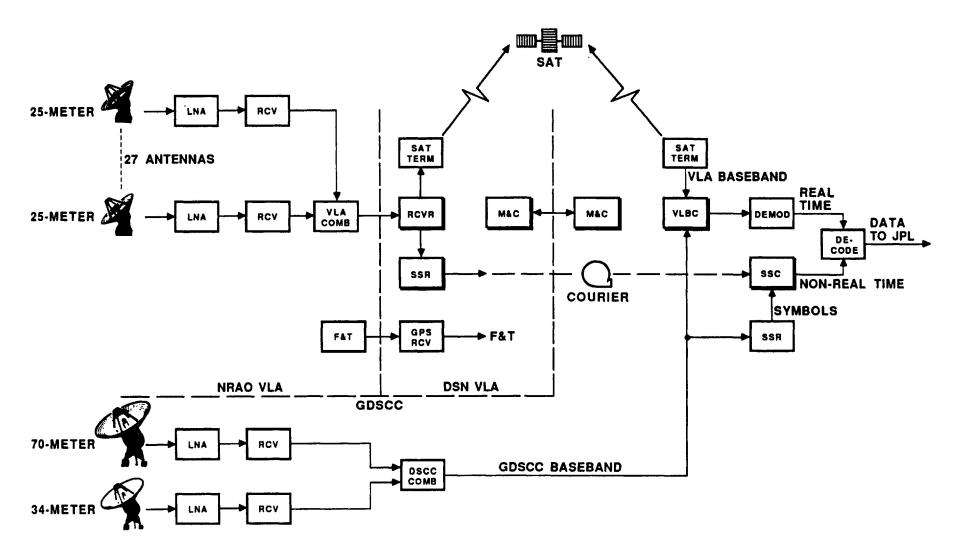




## VGTA PROJECT INTRODUCTION



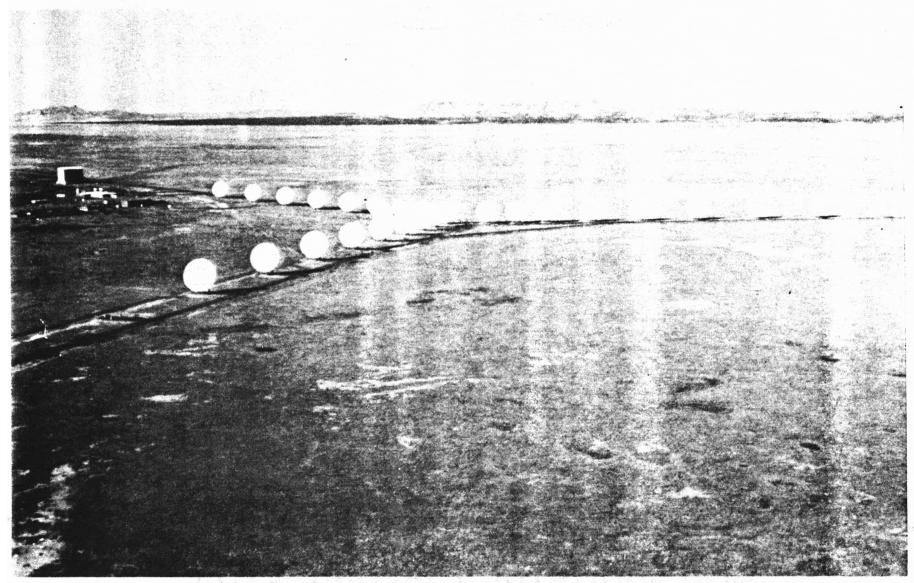




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# VGTA PROJECT INTRODUCTION VLA SITE AERIAL VIEW





## VLA-GOLDSTONE ARRAY FORMAL REVIEW

IMPLEMENTATION PLAN



K.P. BARTOS

**JULY 1987** 

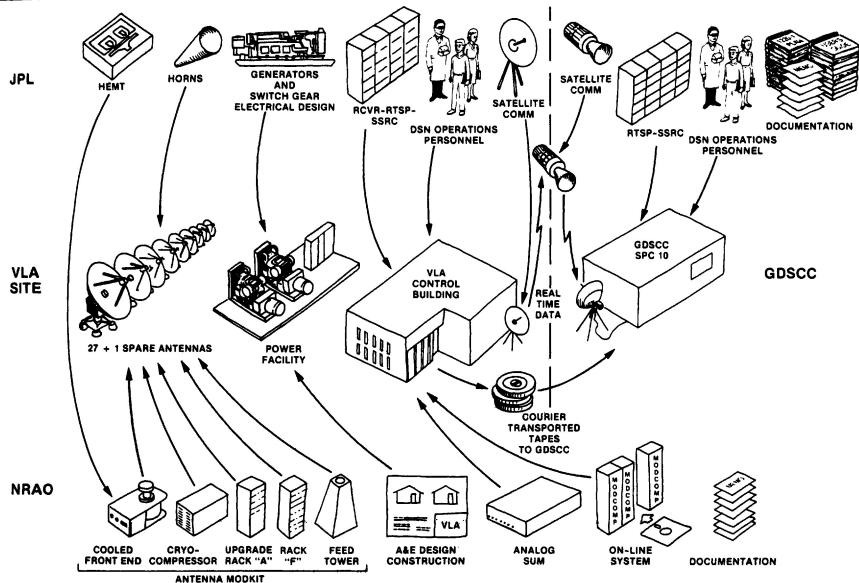
# IMPLEMENTATION PLAN AGENDA



- MAJOR DELIVERABLES
- PHOTOGRAPH LIST

## IMPLEMENTATION PLAN MAJOR DELIVERABLES





# IMPLEMENTATION PLAN PHOTOGRAPH LIST



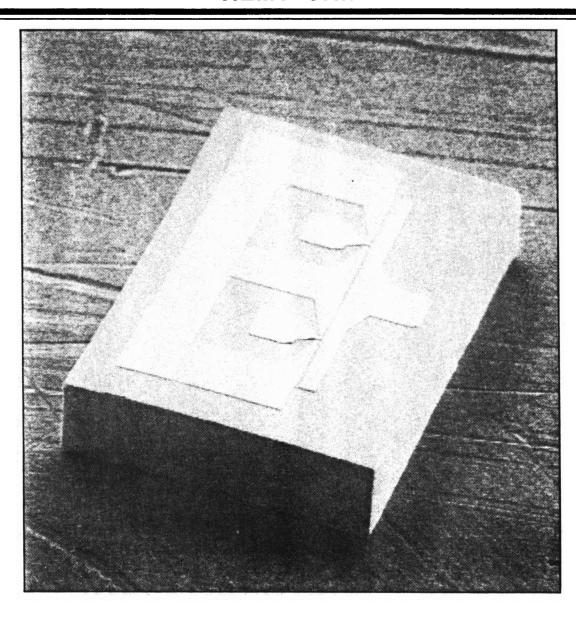
## PHOTO

DESCRIPTION	PHOTO No.
• HEMT CHIP	JPL 3705
VLA AMPLIFIER MODULE	JPL 3617 BC; JPL 3685 B; 333 7410 AC; 333 7411 AC
• COOLED FRONT END	JPL 3753 CC; JPL 3754 AC
• HORN	333-7575-BC
ANTENNA INSTALLATION	JPL 3767 CC; JPL 3767 AC; JPL 3766 BC; JPL 3765 DC
• POWER FACILITY	JPL 3688 BC; JPL 3761 BC; JPL 3761 DC
• ANALOG SUM	JPL 3772 AC; JPL 3752 AC
• VLA RECEIVER	JPL 3700 AC
VLA VLBC	JPL 3701 BC
• RTSP	JPL 3701 AC
• SSRC	JPL 3700 BC

# IMPLEMENTATION PLAN HEMT CHIP



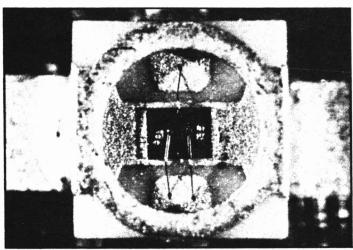




# IMPLEMENTATION PLAN VLA AMPLIFIER MODULE



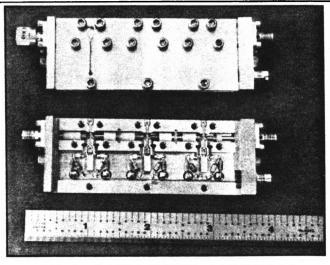




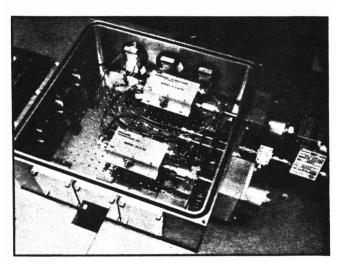
**HEMT PACKAGED DEVICE** 



**TEST CONFIGURATION** 



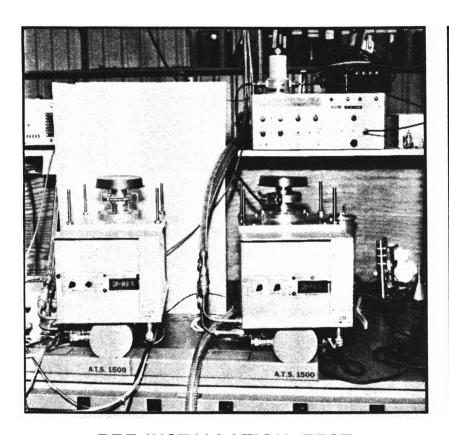
**VLA AMPLIFIER MODULE** 



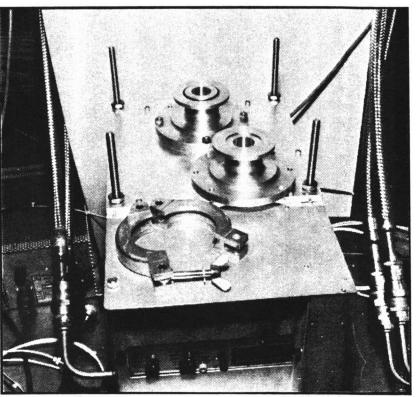
TEST FIXTURE

# IMPLEMENTATION PLAN COOLED FRONT-END





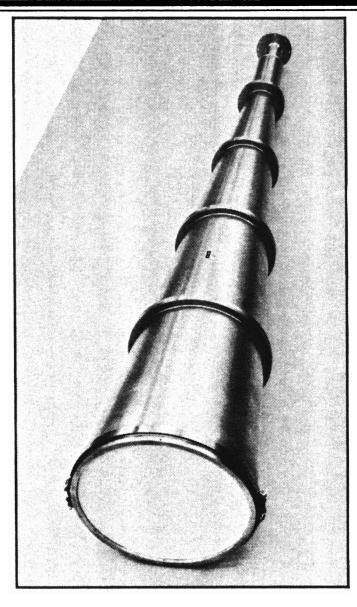




HORN QUICK DISCONNECT

# IMPLEMENTATION PLAN HORN



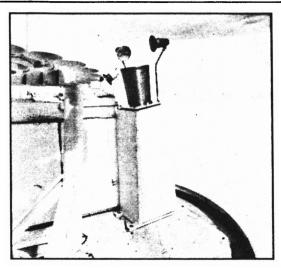


**VLA-GOLDSTONE ARRAY FORMAL REVIEW** 

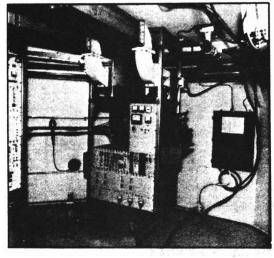
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## IMPLEMENTATION PLAN **ANTENNA INSTALLATION**

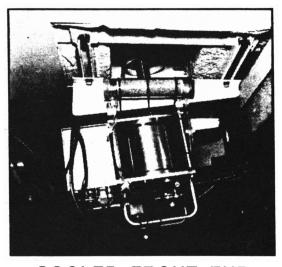




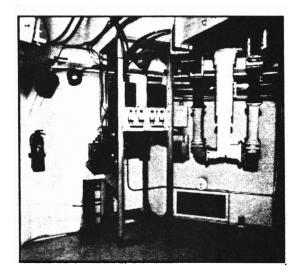
**FEED TOWER AND HORN** 



**UPGRADED RACK "A"** 



**COOLED FRONT END** 

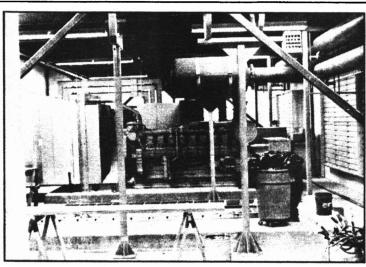


RACK "F"

\_JPL

# IMPLEMENTATION PLAN POWER FACILITY

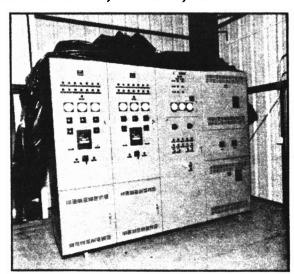




"AS PURCHASED" FROM MICRON TECHNOLOGY, BOISE, ID



**BUILDING CONSTRUCTION, MAY 1987** 



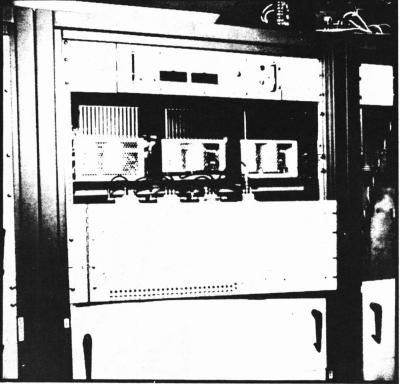
**SWITCH GEAR** 

\_JPL

## IMPLEMENTATION PLAN ANALOG SUM





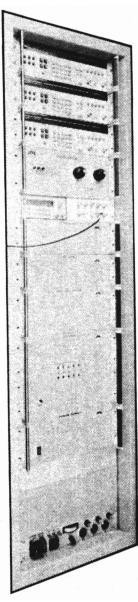


**CORRELATOR** 

DETAIL

# IMPLEMENTATION PLAN VLA RECEIVER





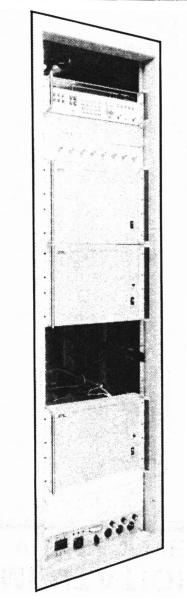
**VLA-GOLDSTONE ARRAY FORMAL REVIEW** 

6485-3835g

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# IMPLEMENTATION PLAN VERY LONG BASELINE COMBINER (VLBC)



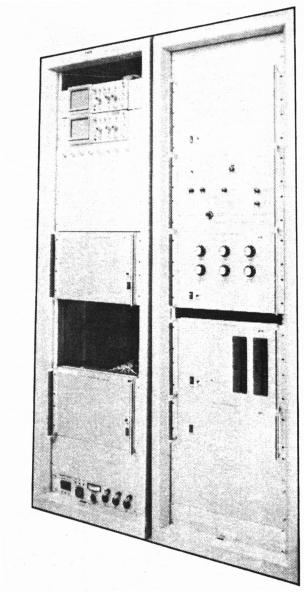


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**VLA-GOLDSTONE ARRAY FORMAL REVIEW** 

# IMPLEMENTATION PLAN REAL TIME SIGNAL PROCESSOR (RTSC)





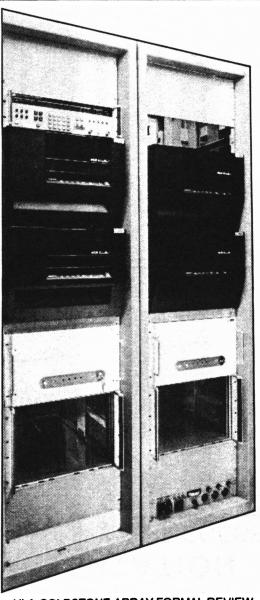
**VLA-GOLDSTONE ARRAY FORMAL REVIEW** 

6485-3837g VLA-GOLDSTOI

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# IMPLEMENTATION PLAN SYMBOL STREAM RECORDER AND COMBINER (SSRC)





VLA-GOLDSTONE ARRAY FORMAL REVIEW

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# VLA-GOLDSTONE ARRAY FORMAL REVIEW

SYSTEM DESIGN ISSUES



D.W. BROWN

**JULY 1987** 

# SYSTEM DESIGN ISSUES AGENDA



- VLA PROCESSOR/COMBINING
- DATA GAPS IN VLA SIGNAL
- HIGH ELECTRON MOBILITY TRANSISTORS (HEMT's)
- SYMBOL STREAM RECORDING AND COMBINING
- PRIMARY POWER GENERATION
- INTERSITE COMMUNICATIONS
- AVAILABILITY ESTIMATES
- TELECOM LINK DESIGN
- SYSTEM TEST PLAN/STATUS
- DSN OPERATING PREDICTS

# SYSTEM DESIGN ISSUES VLA ON-LINE SYSTEM



- DATA COLLECTED FROM TWENTY-SEVEN ANTENNAS OVER TIME-SHARED WAVEGUIDE
- MONITOR AND CONTROL TRANSMITTED OVER TIME-SHARED WAVEGUIDE
- PROCESSOR OPERATED IN AUTOPHASING (VLBI) MODE TO ENABLE COMBINING OF ANALOG SUM
- ANALOG SUM OUTPUTS VIRTUAL SINGLE APERTURE SIGNAL TO DSN FOR TELEMETRY DEMODULATION, REAL-TIME SATELLITE TRANSMISSION, AND RECORDING
- OBSERVING FILES GENERATED ON-SITE BY JPL/DSN SETS FRONT-END BAND, OSCILLATORS, FILTERS, POINTS AND PHASES ANTENNAS

# SYSTEM DESIGN ISSUES VLA PROCESSOR/COMBINING



#### **AUTOPHASING PROCESS**

- VLA CORRELATOR DETECTS DIFFERENTIAL PHASE FOR EACH BASELINE
- ON-LINE COMPUTER SOLVES FOR INDIVIDUAL ANTENNA PHASES
  - RELATIVE TO REFERENCE ANTENNA (CURRENT CAPABILITY)
  - GLOBALLY, USING ALL BASELINES (BEFORE VOYAGER OPS)
- INDIVIDUAL PHASES ARE USED AS ERROR SIGNAL IN FEEDBACK LOOP TO SECOND LOCAL OSCILLATOR

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# SYSTEM DESIGN ISSUES VLA PROCESSOR/COMBINING



#### **AUTOPHASING ISSUES**

- SUFFICIENT SNR ON VOYAGER TO GET GOOD PHASE SOLUTION
- MINIMAL COMBINING LOSS EXPECTED WITH GLOBAL AUTOPHASING
- BROAD BAND CONTINUUM MODE PLANNED TO EASE TUNING REQUIREMENTS
- SPECTRAL LINE MODE PLANNED FOR EMERGENCY LOW SNR
- •TROPOSPHERIC EFFECTS TEND TO DRIVE PHASE OSCILLATIONS
- COMPACT ARRAY TO MINIMIZE DIFFERENTIAL TROPOSPHERICS
- DETERMINATION OF OPTIMAL PHASE-LOOP DESIGN vs LOOP-TIME DELAY AND TROPOSPHERIC EFFECTS



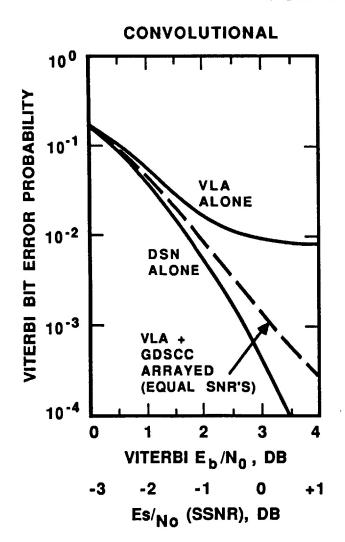
#### **ANALYSIS UPDATE FOR CONCATENATED CODING**

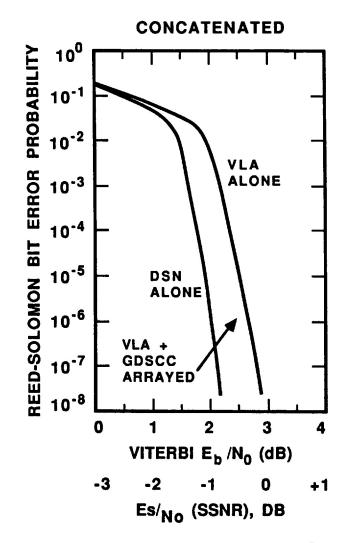
- NOMINAL GAP LENGTH CORRESPONDS ON THE AVERAGE TO EIGHT REED-SOLOMON SYMBOLS PER CODEWORD (CODE CAN CORRECT SIXTEEN SYMBOL ERRORS PER CODEWORD)
- EFFECTIVE GAP LENGTH IS SHORTENED BY ERROR CORRECTION CAPABILITY OF THE CONVOLUTIONAL CODE
- CONVERSELY, THE EFFECTIVE LENGTH IS INCREASED DUE TO EDGE EFFECTS
- NEW "TWO-LEVEL" MODEL YIELDS ERROR-FREE PERFORMANCE FOR NOMINAL VOYAGER DATA RATES FOR ANY VLA-GOLDSTONE MIX
- RESONANCES BETWEEN GAP FREQUENCY AND (NON-VOYAGER)
  DATA RATES HAVE BEEN IDENTIFIED WHICH DEGRADE PERFORMANCE
  FOR HIGH RATIOS OF VLA-TO-GOLDSTONE MIX (EFFECT UNDER
  CONTINUING STUDY)

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#### **CODED ERROR RATES**







#### HARDWARE SIMULATIONS

- PURPOSE: VERIFY PERFORMANCE WITH 1.6 MSEC GAPS
- CONFIGURATION: MCCC SIM/CTA 21/VOYAGER DACS/MIPL
- DEMONSTRATED COMPATIBILITY WITH DSN EQUIPMENT
- DEMONSTRATED COMPATIBILITY WITH FRAME SYNCHRONIZATION
- VERIFIED REED-SOLOMON PERFORMANCE
  - WITH NOMINALLY EQUAL VLA AND GDSCC SIGNALS
  - WITH VLA AND DSS 14 ONLY AND WITH VLA STAND-ALONE
- VERIFIED CONVOLUTIONAL PERFORMANCE
  - AS PREDICTED AT JUNE 1984 REVIEW
  - ERROR RATES UP TO 1 PERCENT FOR VLA STAND-ALONE CASE



#### **GAPPED BER SIGNAL\***

#### • REED-SOLOMON CODED PERFORMANCE

CONDITION	ARRAY SSNR	R-S BER
• VLA SNR << GDSCC SNR	0.0 DB	<<1 x 10 <sup>-5</sup>
VLA SNR ≥ GDSCC SNR	+0.5 DB	< 1 x 10 <sup>-5</sup>
• CONVOLUTIONAL CODED PERFOR	RMANCE	
CONDITION	ARRAY SSNR	MCD BER
W 4 4 WD 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	0.0.00	- 40-3

• VLA SNR << GDSCC SNR	0.0 D + 1.5 D	OB<	5 x 10 <sup>-3</sup> 5 x 10 <sup>-5</sup>
• VLA SNR = GDSCC SNR	+ 0.5 D + 3.0 D	OB<	5 x 10 <sup>-3</sup> 5 x 10 <sup>-5</sup>
• VLA SNR >> GDSCC SNR	> 0 E	OB<	2.5% OF GDSCC
• VLA STAND-ALONE	> 0 D	OB<	1.5 x 10 <sup>-2</sup>

<sup>\*</sup> INCLUDES THE EFFECT OF THE 1.6 MSEC/52 MSEC GAP IN THE VLA DATA STREAM AS WELL AS LOSSES IN THE VERY LONG BASELINE COMBINER

# SYSTEM DESIGN ISSUES HIGH ELECTRON MOBILITY TRANSISTORS



#### **BACKGROUND AND STATUS**

- JOINT JPL/NRAO EFFORT PLACED INITIAL CONTRACT WITH GENERAL ELECTRIC IN 1984
- EARLY APPLICATION TO CRYOGENIC X-BAND SERVICE SHOWED GREAT PROMISE IN 1984-85
- SUCCESSFUL APPLICATION TO INITIAL X-BAND INSTALLATIONS AT THE VLA LED TO IMPLEMENTATION DECISION IN 1986
- TO DATE, NINETEEN HEMT FRONT-END RECEIVERS PRODUCED AT CHARLOTTESVILLE WITH EIGHT INSTALLED AT THE VLA
- LATEST HEMT PRODUCTION BATCH SHOWING EVEN LOWER NOISE AND HIGHER YIELD THAN PREVIOUS PRODUCTION

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**JPL** 

# SYSTEM DESIGN ISSUES HIGH ELECTRON MOBILITY TRANSISTORS



#### **RELIABILITY**

- ACCELERATED LIFE TESTING BY GE, SONY AND TRW REPORT RESULTS SIMILAR TO STANDARD GAS FETS
- NO HEMT DEVICE FAILURE IN AN ASSEMBLED CCR PACKAGE TO DATE
- SURVIVED DIRECT LIGHTNING HIT TO DSS 13 ANTENNA
- DIRECT INTERCHANGEABILITY OF HEMTS WITH STANDARD FETS PERMITS FALL-BACK IN WORST CASE SCENARIO OF UNFORESEEN FUTURE OF HEMT APPLICATION

# SYSTEM DESIGN ISSUES HIGH ELECTRON MOBILITY TRANSISTORS



#### BENEFITS TO NRAO, DSN, AND VOYAGER

- VLA X-BAND SYSTEM NOISE TEMPERATURE AT ZENITH PROVIDES SENSITIVE ASTRONOMY BAND AND MARGIN FOR VLA-VOYAGER SYSTEM DESIGN
  - STANDARD FET 40 45 KELVIN
  - 1986 HEMT's \_\_\_\_\_ 25 32 KELVIN
  - PREDICTED 1987 HEMT's \_\_\_\_\_ 24 28 KELVIN
- DIRECT APPLICATION OF HEMT/CCR DESIGN TO THE VERY LONG BASELINE ARRAY PROJECT
- DSN S-BAND TRAVELING WAVE MASER PERFORMANCE CAN NOW BE EQUALLED WITH A HEMT/CCR DESIGN

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6485-3546a

# SYSTEM DESIGN ISSUES SYMBOL STREAM RECORDING AND COMBINING



#### BACKGROUND

- PROVIDES REDUNDANCY TO THE REAL-TIME SYSTEM BY RECORDING TELEMETRY SIGNAL AT BOTH SITES FOR POST-PASS PLAYBACK AND COMBINING AS REQUIRED
- BASEBAND RECORDING UTILIZED FOR THE PARKES-CANBERRA ARRAY FOR VOYAGER URANUS ENCOUNTER
- SYMBOL STREAM RECORDING ADVANTAGES
  - REDUCED BANDWITH AND STORAGE REQUIREMENTS
  - REDUCED COMPLEXITY AND IMPROVED RELIABILITY THROUGH DEDICATED EQUIPMENT DESIGN
- ADVANCED SYSTEM TECHNOLOGY DEMONSTRATION AT URANUS ENCOUNTER ESTABLISHED FEASIBILITY

# SYSTEM DESIGN ISSUES SYMBOL STREAM RECORDING AND COMBINING



#### SYSTEM LEVEL FUNCTIONAL REQUIREMENTS FOR NEPTUNE

- PROVIDE REAL-TIME RECORDING AT EACH SITE AND POST-PASS PLAYBACK AND COMBINING AT GOLDSTONE
- INITIATE PLAYBACK WITHIN NINE HOURS OF END OF PASS
- REAL-TIME MONITORING TO ASSURE VALID RECORDINGS
- OUTPUT COMBINED SIGNAL THROUGH GOLDSTONE DECODER
- OUTPUT DECODED ERROR RATE WITHIN 0.2 DB OF IDEAL
- MAXIMUM BIT RATE OF 25.2 KBPS (50.4 KSPS)

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# SYSTEM DESIGN ISSUES SYMBOL STREAM RECORDING AND COMBINING



#### KEY CHARACTERISTICS

- DEDICATED DSN STANDARD TELEMETRY DEMODULATORS AND TAPE TRANSPORTS
- ONE HOUR PER TAPE (8-BIT RECORDING) AT MAXIMUM DATA RATE
- CPU AND CONTROLLER FOR RECORD, PLAYBACK AND COMBINING FUNCTIONS
- REAL-TIME RECORDING MONITOR FUNCTIONS
  - TELEMETRY DEMODULATOR PROVIDES PRECISION SIGNAL-TO-NOISE RATIO ESTIMATES
  - CPU COMPUTES SIGNAL-TO-NOISE RATIO TO VALIDATE DATA BEING RECORDED
- OPERABLE FROM DEDICATED PC TERMINAL OR FROM VGTA REAL-TIME MONITOR AND CONTROL TERMINAL
- FULL REDUNDANCY TO MINIMIZE MEAN TIME TO RECOVERY

# SYSTEM DESIGN ISSUES PRIMARY POWER GENERATION



- PRELIMINARY STUDY IDENTIFIED QUALITY AND RELIABILITY DEFICIENCIES IN EXISTING POWER SYSTEM
- TWO-YEAR POWER LINE MONITORING CONFIRMED DEFICIENCIES
- •PLAN DEVELOPED FOR ON-SITE DIESEL ELECTRIC PLANT TO SUPPORT ALL VOYAGER PASSES AND CRITICAL TESTS
- EXISTING INDUSTRIAL FACILITY (NEAR NEW) PURCHASED FOR PERMANENT RELOCATION TO THE VLA
- INSTALLATION NOW UNDERWAY AND SCHEDULED FOR MID 1988 READINESS

# SYSTEM DESIGN ISSUES INTERSITE COMMUNICATIONS



#### **SERVICES**

- VLA GOLDSTONE INTERFACE VIA EARTH SATELITE
  - FIVE-MEGAHERTZ VIDEO GRADE CHANNEL FOR BASEBAND DATA RETURN (ONE-WAY)
  - THREE VOICE CIRCUITS (INTERCOM)
  - TWO DATA CIRCUITS (DSN EQUIPMENT CONTROLLERS AND SLOW SCAN TV)
- DEDICATED TELEPHONE CIRCUITS
  - JPL VLA ONE-WAY TELETYPE (PREDICTS)
  - TWO DIAL PHONES (ADMIN AND EMERGENCY OPERATIONS)

# SYSTEM DESIGN ISSUES INTERSITE COMMUNICATIONS



#### **IMPLEMENTATION**

- NASCOM HAS ACCEPTED THE IMPLEMENTATION OF THE SATELLITE SERVICES BY EARLY 1988
- TECHNICAL REQUIREMENTS DOCUMENT RELEASED
  - SIMILAR TO PARKES-TIDBINBILLA SPECIFICATION
- RECENT GOLDSTONE-SATELLITE-GOLDSTONE TELEMETRY TEST ON SIMILAR LINK HAS PROVEN EXPECTED TRANSPARENCY
- PLANS INCLUDE REAL-TIME DATA RETURN FROM THE VLA FOR THE MID 1988 VOYAGER DUAL PROCESSOR TEST

# SYSTEM DESIGN ISSUES AVAILABILITY ESTIMATES



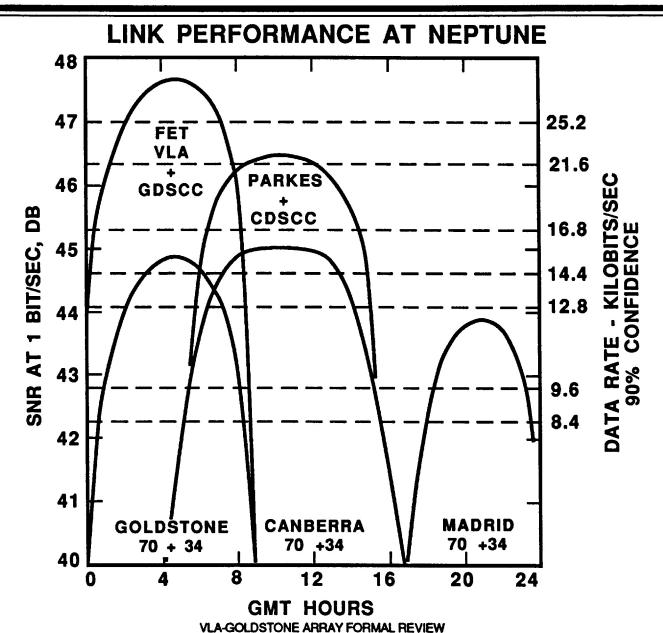
ELEMENT	COMMENT	REAL TIME	
● VGTA M&C (MAN/MACHINE)	BOTH SITES	0.99	0.98
• INTERSITE LINK		0.99	
• REAL-TIME COMBINING	100 % SPARES	0.99	
• VLA AND GDSCC RECORDING	HOT SPARES		0.98
• TAPE LOSS/DAMAGE	COURIER SERVICE		0.98
• NRT PLAYBACK AND COMBINING			
• SPC 10 DTM, LMC, GCF		0.99	1.00
BASEBAND CHANNEL      VGTA RECEIVER			
• VGTA BACK END	RT/NRT		0.99
• VLA COMMON SYSTEM	REDUNDANCY/SPAR	ES	0.98
• VLA FRONT ENDS			-
• VLA SUMMER WEATHER			
• GDSCC SUB-ARRAY	DSS 14+15+SPC 10/I	RTC	0.97
• VGTA OVERALL		•	<0.92

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### SYSTEM DESIGN ISSUES







JPL

# SYSTEM DESIGN ISSUES TELECOM LINK DESIGN



#### **CONTROL TABLE**

	FET VLA (COMMITTED)	GDSCC	HEMT VLA (PLANNED)	EST UNCERT
VOYAGER 2 SIGNAL	***************************************	5 x 10 <sup>-21</sup> (W/M SQ)		± 0.6
ANTENNA GAIN		74.0 DB (70 M) 67.6 (34 M)	64.6 DB	
• LOCAL SUMMED GAIN	78.6 DB	74.9 DB (GDSCC)	78.6 DB	± 0.5
• POINT/QUANT/COMB LOSS.	-1.2 DB	- 0.2 DB	- 1.2 DB	+ 0, -0.2
• SYSTEM TEMP (30 DEG)	50 K	25 K	35 K	± 0.5
• MOD AND SYSTEM LOSS				•
• SSNR @ 21.6 KBPS	-1.0 DB	- 0.7 DB	+ 0.5 DB	
• ARRAY GAIN (VGTA/GDSCC	2.8	DB 3.6 DE	3	MIDPASS
• SSNR @ 21.6 KBPS	<b>2.</b> 1 !	DB 2.9 DE	}	DRY

# SYSTEM DESIGN ISSUES VGTA SYSTEM TEST PLAN/STATUS



		Т						Т	_			-	19	87					T.		19	88				1989																	
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3	ARRAY CONFIGURATION		D		1	1		В							D		*		A		*	ŀ	*	3	Ġ		*		D		*	A	L	*		В		*	C			ها	1
4	VLA ON-LINE SYSTEM				l	l								L		L		Δ			_	<u> </u>	L	Ц		$\perp$				Δ	$\perp$	<u>L</u>	Ŷ	$\coprod$		$\Box$	$oldsymbol{\mathbb{I}}$				Т	Т	7
5	• VLA-DSN INTERFACE				l	1			A																Ц,		يا	<u> </u>						$\prod$			$oxed{oxed}$	brack	Γ	Π	Т	Т	7
6	• JPL TRIAL INSTALLATIONS				J	I																									$\prod$			$\prod$		$\prod$	T	Τ	Γ	П		T	7
7	• SUBSYSTEM ACCEPTANCE	Π		H/V	N	I	Ι		3/W						\$/\ 	W L						ÀC	Ϋ́R	/RT	SP/	PW	R/S	ŚR	Ċ				I	П		П	$\top$	T	Γ	П		T	7
8	JPL (CTA 21)			$\prod$		I																									$\prod$		L			$\Box$		Τ	Τ	П	П	T	1
9	DATA GAP SIMULATION				Ц	$oldsymbol{J}$											L	Δ																		$\prod$	$\prod$	T	Τ			T	
10	• REAL-TIME EQUIPMENT				$\prod$													Δ	Δ													floor						m I	$\mathbb{I}$	$\prod$		Ι	
11	• RECORDING EQUIPMENT	L																		Δ	$\blacksquare$																$oxed{I}$					Т	
12	GDSCC (GOLDSTONE)	I			$\prod$	$oxed{oxed}$																											L						$\prod$		$\prod$	$\top$	
13	• EXISTING SATELLITE LINK	L			$\prod$										N								L								$\coprod$		$oldsymbol{\mathbb{L}}$						$\mathbf{I}$				
14	• COMBINING DEMO	L			П											L	L	L	Δ												Ц		L									T	
15	SUBSYSTEM ACCEPTANCE																									Ŗ.	TŠF	P/S	SRO	3			$oldsymbol{\mathbb{L}}$							$\prod$	П	T	
16	INTERSITE COMMUNICATIONS	$\mathbb{L}$																																			$\prod$		m I		П	T	7
17	• NASCOM ACCEPTANCE	$\mathbf{I}$			$\prod$	$\perp$																			A							floor						$oxed{oxed}$	m I	$\prod$	$\prod$	T	
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19	VGTA SYSTEM										$\square$	·								L					Ц				L		$\prod$								$oxed{L}$				
20	VOYAGER NDPP TEST																	L		L					Ц		_	Δ	L		Ш		$\prod$										
21	• EPT, SPT, S/C DEMO																			L				L								Δ	1						$\prod$				
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23	• VOYAGER SUPPORT																								$\prod$						$\coprod$	$\prod$	$\perp$					<u></u>	_\_				

\* = ARRAY HYBRID CONFIGURATIONS

V= RESCHEDULED

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# SYSTEM DESIGN ISSUES DSN OPERATING PREDICTS



- NETWORK SUPPORT SUBSYSTEM TO GENERATE AND TRANSMIT THE FOLLOWING VOYAGER 2 PREDICTS TO THE VLA
- ANTENNA POINTING RIGHT ASCENSION AND DECLINATION (APPARENT TRUE OF DATE)
- X-BAND RECEIVED FREQUENCY (FOR BOTH VLA ON-LINE SYSTEM AND THE DSN RECEIVER)
- SEQUENCE OF EVENTS (SUBSET OF SPC 10)
- TELEMETRY PREDICTS (SUBSET OF SPC 10)

# VLA-GOLDSTONE ARRAY FORMAL REVIEW

NRAO IMPLEMENTATION

JPL

W.D. BRUNDAGE

**JULY 1987** 

# NRAO IMPLEMENTATION AGENDA



- FRONT-END SYSTEM
- BACK-END SYSTEM
- ANALOG SUM
- ON-LINE SYSTEM
- PERFORMANCE TESTS
- RELIABILITY
- SCHEDULE

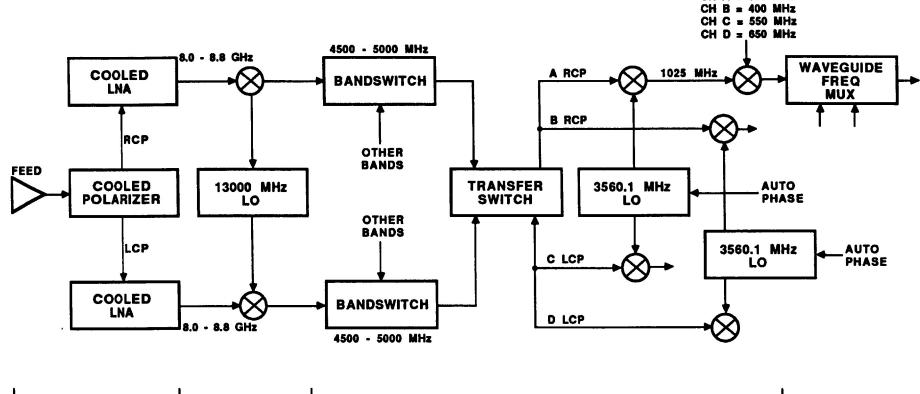
### NRAO IMPLEMENTATION

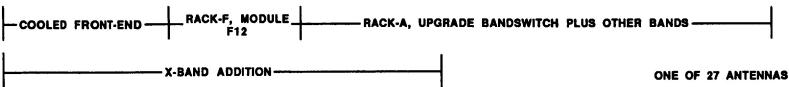




CH A = 300 MHz

#### **BLOCK DIAGRAM**





## NRAO IMPLEMENTATION

#### FRONT-END SYSTEM

#### FEED AND COOLED FRONT-END

- 28 JPL FEED HORNS TO VLA
  - INSTALLED DURING ANTENNA OVERHAUL
  - FINISH DECEMBER 1988
- 30 COOLED FRONT-ENDS MADE BY NRAO CENTRAL DEVELOPMENT LAB
- ALL HAVE HEMT AMPLIFIERS
  - TYPICAL NOISE TEMP ~ 14 KELVIN
  - NOISE TEMP WITH NEW GE HEMT'S 8 TO 11 KELVIN
- TYPICAL T<sub>cfe</sub> AT FEED FLANGE
  - •~19 KELVIN
  - •~15 KELVIN WITH NEW HEMT's
- ●19 COOLED FRONT-ENDS AT VLA, BALANCE OF 11 AT VLA BY **DECEMBER 1987**
- INSTALLED ON ANTENNAS DURING OVERHAUL
  - FINISH DECEMBER 1988

### NRAO IMPLEMENTATION

#### FRONT-END SYSTEM



#### **RACK-F AND RACK-A**

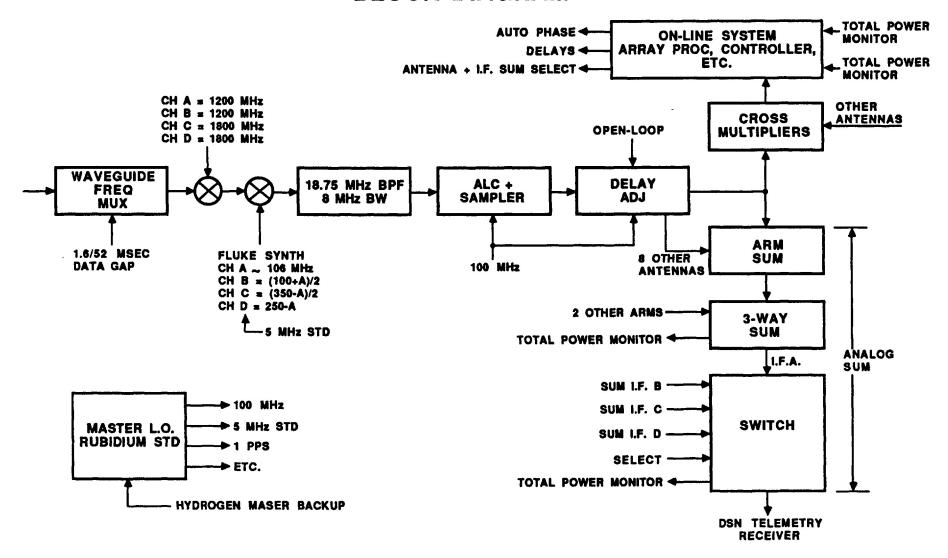
- RACK-F ON ANTENNA CONTAINS
  - CONTROL AND MONITOR INTERFACES FOR COOLED FRONT-END (CFE) AND FREQUENCY CONVERTER
  - FREQUENCY CONVERTER MODULE-F12
    - RF IN: 6.8 10.7 GHz
    - I.F. OUT: 4.5 5.0 GHz
    - L.O.: 11.8 15.2 GHz = N\*0.60 + -0.20 GHz, N = 20, 21, ..., 25
- RACK-F INSTALLED DURING ANTENNA OVERHAUL. 30 MODULE SETS WILL BE BUILT
- RACK-A ON ANTENNA CONTAINS VLA FRONT-ENDS AND BANDSWITCH TO RACK-F AND X-BAND
- RACK-A SPLITS EACH POLARIZATION INTO 2 I.F. CHANNELS AND PHASE SHIFTS L.O.'s
- RACK-A UPGRADE REQUIRED FOR BANDSWITCH. INSTALLED DURING OR BEFORE OVERHAUL

#### NRAO IMPLEMENTATION

#### **BACK-END SYSTEM**



#### **BLOCK DIAGRAM**



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# NRAO IMPLEMENTATION BACK-END SYSTEM



#### BASEBAND FILTERS AND MASTER L.O.

- BASEBAND FILTERS PROVIDED BY JPL FOR ALL FOUR I.F.'s OF EACH ANTENNA
  - 18.75 MHz CENTER, 8 MHz BANDWIDTH
  - SELECTED IN BASEBAND MODULE-T4 AUX POSITION BY ON-LINE SYSTEM
  - LOCATED IN RACK-D WITH BASEBAND FREQUENCY CONVERTERS AND FILTER SYSTEM
- MASTER L.O. SYSTEM
  - RUBIDIUM FREQUENCY STANDARD HP 5065B, HYDROGEN MASER BACKUP
  - PROVIDES 5 MHz STANDARD AND 1 PULSE PER SECOND TO DSN EQUIPMENT
  - FLUKE SYNTHESIZERS SET BASEBAND FREQUENCY CONVERTERS

# NRAO IMPLEMENTATION BACK-END SYSTEM



#### CORRELATOR AND AUTOPHASE

#### • CORRELATOR

- EACH I.F. COMPLEX-SAMPLED (3-LEVEL, 2-BIT) AT 100 MHz FOR ALL BANDWIDTHS
- SAMPLED DATA AT 100 MHz DELAYED TO REMOVE ANTENNA SPATIAL PHASE
- DELAYED SAMPLED DATA AT 100 MHz SENT TO ANALOG SUM AND MULTIPLIERS
- MULTIPLIERS CROSS-MULTIPLY 351 COMBINATIONS OF ANTENNAS IN EACH I.F.
- COMPLEX CROSS-PRODUCTS GO TO ARRAY PROCESSOR TO BE INTEGRATED FOR 10 SECONDS

#### AUTOPHASE

• ON-LINE SYSTEM USES ARRAY PROCESSOR OUTPUT TO CALCULATE GLOBAL PHASE AND SET FRONT-END L.O. PHASE SHIFTERS

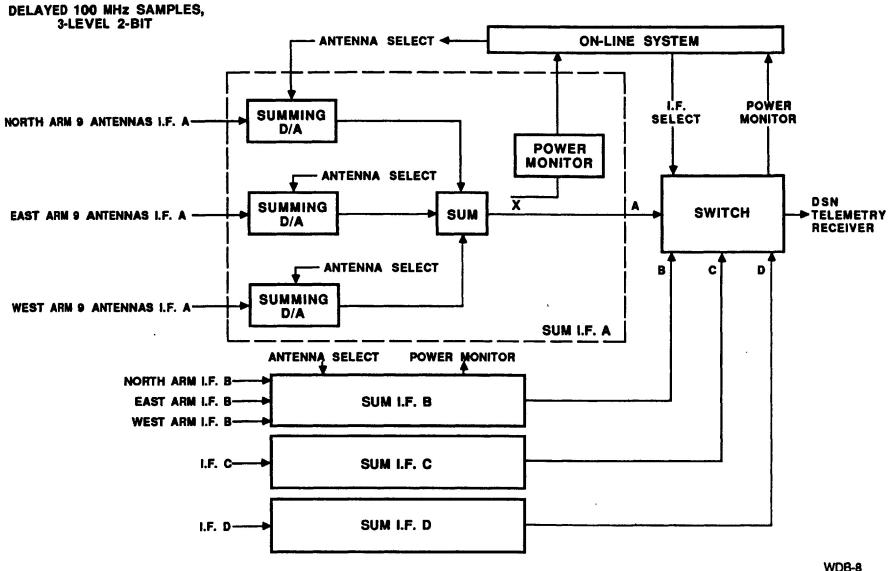
### NRAO IMPLEMENTATION



#### **ANALOG SUM**



#### **BLOCK DIAGRAM**



WDB-8 7-8-87

# NRAO IMPLEMENTATION ANALOG SUM



#### SUM AND SWITCH SPECIFICATIONS

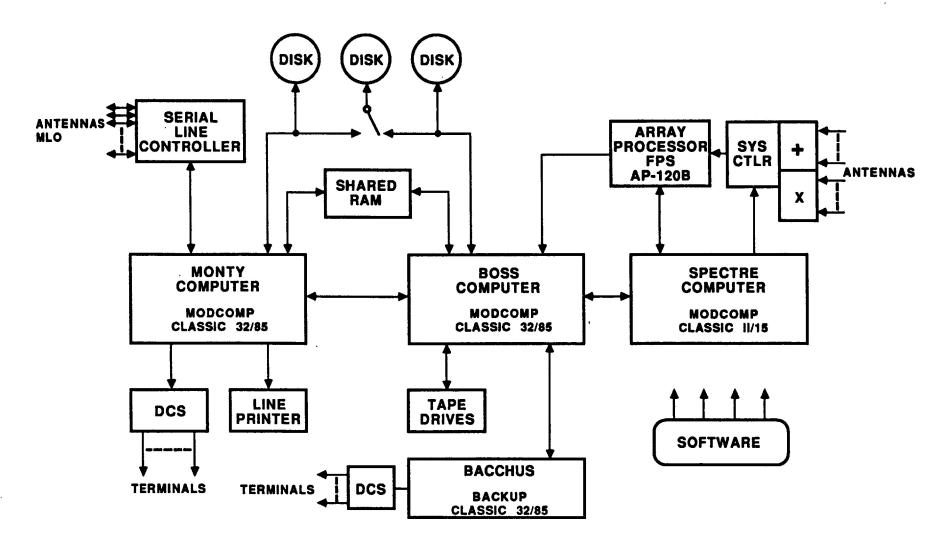
- SUM SPECIFICATIONS
  - ONE UNIT FOR EACH OF 4 I.F. CHANNELS PLUS 5th SPARE
  - INPUT SAMPLED DATA AT 100 MHz FROM EACH ANTENNA
  - OUTPUT ANALOG SUM VOLTAGE TO 50 MHz FOR ANTENNAS SELECTED BY ON-LINE SYSTEM
  - TOTAL POWER OUTPUT MONITOR TO ON-LINE SYSTEM
  - SPURIOUS SIGNALS < -94 DBM WHEN DELIVERING -16 DBM
- SWITCH SPECIFICATIONS
  - CONNECT ONE OF 4 ANALOG SUMS TO DSN RECEIVER AS SELECTED BY ON-LINE SYSTEM
  - LOSS < 4 DB
  - TOTAL POWER OUTPUT MONITOR TO ON-LINE SYSTEM

### NRAO IMPLEMENTATION





#### **BLOCK DIAGRAM**



JPL

### NRAO IMPLEMENTATION

#### **ON-LINE SYSTEM**



#### CONTROL AND MONITOR SPECIFICATIONS

- GLOBAL AUTOPHASING ON VOYAGER SIGNAL IN BOTH I.F.'s OF EITHER POLARIZATION IN CONTINUUM OR SPECTRAL LINE MODE
  - RMS RESIDUAL PHASE < 12 DEGREES IN 10 SECOND INTEGRATION WITHOUT DISCONTINUITIES
  - ACQUISITION TIME < 5 MINUTES
- ALL STANDARD VLA CONTROL FUNCTIONS PLUS JPL SPECIALS
  - EFFECT OBSERVING FILE CHANGES < 10 MINUTES
  - FILES SET FREQUENCY, SELECT IF CHANNEL AUTOPHASE AND SUM, DELETE ANTENNAS, ETC.
- MONITOR AND DISPLAY FOR DSN-VLA OPERATIONS AND EQUIPMENT SUPERVISORS
  - CHECKER, DIAGNOSTICS, ANTENNA PHASE AND NOISE TEMPS, DELETED ANTENNAS, ETC.

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# NRAO IMPLEMENTATION PERFORMANCE TESTS



#### APERTURE EFFICIENCIES AND NOISE TEMPERATURE

• APERTURE EFFICIENCY ~ 0.62 ± 0.03
• RCP AND LCP EFFICIENCIES CONSISTENT
• T <sub>sys</sub> (FET, ZENITH) ~ 49 ± 3 KELVIN
• T <sub>sys</sub> (HEMT, ZENITH) ~ 32 ± 3 KELVIN
• T <sub>sys</sub> (HEMT, 30 DEG ELEV) ~ 35 ± 3 KELVIN
• T <sub>cfe</sub> (HEMT) AT FEED FLANGE ~ 17 ± 2 KELVIN
• T <sub>ant</sub> (ZENITH) ~ 15 KELVIN
T <sub>ant</sub> = T <sub>sys</sub> - T <sub>cfe</sub>
• T <sub>ant</sub> (30 DEG ELEV)~ 18 KELVIN

# NRAO IMPLEMENTATION PERFORMANCE TESTS



#### **G/T RATIO**

● VLA 25-METER ANTENNA G/T 4.859 x 10 <sup>6</sup> x EFF/T <sub>sys</sub>
• G/T (HEMT, ZENITH) $\sim$ 9.40 +/- 0.60 x 10 <sup>4</sup> K <sup>-1</sup> = 49.7 DB/K
• G/T (HEMT, 30 DEG ELEV)
● G/T (27 HEMT, 30 DEG ELEV)~ ~ 63.7 DB/K
-1.0 DB QUANTIZATION
-0.3 DB AUTOPHASING
62.4 DB/K

- $\bullet$  FOR A 64-METER ANTENNA WITH 50% EFFICIENCY, 25 K T<sub>sys</sub>, G/T = 58.0 DB/K
- PREDICT PHASED VLA HAS 4.4 DB GAIN OVER A 64-METER ANTENNA

# NRAO IMPLEMENTATION RELIABILITY



#### GOALS

- GOALS SET BY JPL
- VOYAGER SIGNAL AVAILABILITY = 98%
- MEAN TIME TO RECOVER = 4 HOURS (HARDWARE)
- AT LEAST 25 ANTENNAS OPERATIONAL
- MAX 4 ON-LINE SYSTEM CRASHES OF MAX 10 MINUTES EACH DURING ENTIRE RUN OF 40 VGTA TELEMETRY PASSES
- NO OBSERVABLE PHASE DISCONTINUITIES OR DATA GAPS OTHER THAN THE CONTROL CYCLE GAP OF 1.6 MS

# NRAO IMPLEMENTATION RELIABILITY



#### JPL

#### **STATISTICS**

- VLA STATISTICS
  - SIMPLE DOWNTIME AS % OF SCHEDULED ANTENNA TIME; FROM MAINTENANCE DATA
  - SUMMARIES MONTHLY, QUARTERLY, YEARLY
- 1986 STATISTICS

	<u>ANTENNA</u>	+ (	COMM	ON	=	TOT	<u> </u>
• HARDWARE	1.95 %*	***************************************	1.76 '	%	10-00-07-0 <del>7-00-00-00-00-00-00-00-00-0</del>	3.71	%
• SOFTWARE	***************************************	100000110111111111111111111111111111111	0.73	%	41,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	0.73	%
• WEATHER	·······	***************************************	<b>0.</b> 69 '	%	99949499939901999849849849	0.69	%
• HUMAN ERROR	***************************************	*************************	0.61	% <b>**</b>	******************************	0.61	%
• POWER	?	***************************************	0.37	% <u>**</u>	) <del>99902132929</del> 444224442	0.37	%
• TOTAL	 1.95%		4.16 <sup>4</sup>	%		6.11	%

<sup>\*</sup>INCLUDES ALL VLA FREQUENCY BANDS

\*\*SHOULD BE NEGLIGIBLE FOR VGTA OPERATIONS

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# NRAO IMPLEMENTATION RELIABILITY



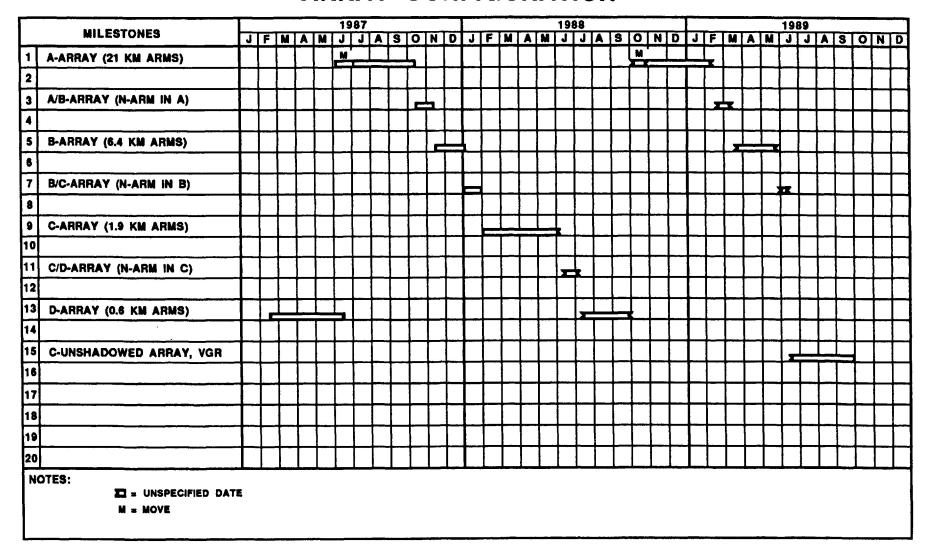
#### **CONCERNS**

- ON-LINE SYSTEM COMPUTER BACKUP IN PLACE
  - TO BE TESTED
- ARRAY PROCESSOR AND CORRELATOR CONTROLLER
  - LIMITED BOARD BACKUP
- HALF-CORRELATOR REDUNDANCY
  - TO BE TESTED
- ELECTRICAL POWER
  - GENERATION SYSTEM BEING INSTALLED
- BURIED POWER CABLES FAILING AT EXPONENTIAL RATE
  - REPLACEMENT PLAN
- CLOCK
  - H-MASER ONLY BACKUP FOR HP RUBIDIUM
- CRYO-REFRIGERATOR
  - 3000 HR MTBF
  - IMPROVEMENT PLAN
- ANTENNA REDUNDANCY THRU 4 I.F. CHANNELS

# NRAO IMPLEMENTATION SCHEDULE



#### ARRAY CONFIGURATION



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# NRAO IMPLEMENTATION SCHEDULE



#### **OPERATIONAL ANTENNAS**

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