DRAFT

Plan for Upgrading Existing Antennas at Stanford's Field Site 515 to Provide a High-bandwidth Satellite Ground Station Facility in Support of Stanford's SSDL CubeSat Satellite Program by Stanford's STAR Laboratory

Submitted by:

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(FBOA is a non-profit 501(c)(3) organization, dedicated to the refurbishment and maintenance of Site 515 for the benefit of Stanford University's faculty and students, as well as Stanford's educational community outreach efforts.)

Contents:

1. Executive Summary

Stanford microsatellites provide a generic space-based platform for a variety of state-of-the-art space research experiments, including spacecraft technology, satellite autonomy, and space tether propellantless propulsion. They are designed, built, and controlled in-flight by Stanford's Space Systems Development Laboratory (SSDL). Stanford microsatellites are intended to be excellent examples of simple, fast, cheap, flexible and intelligent microsatellite design.

To support advanced CubeSat missions now being planned, SSDL needs greatly increased downlink bandwith capability for higher data transfer, as well as higher ground station sensitivity for increasingly distant orbits and trajectories.

SSDL has determined that the existing 60 foot diameter dish antennas at Stanford's Field Site 515 are well suited for its long-distance high bandwidth communication needs. A series of expert inspections revealed that the antennas are structurally sound, their reflector surfaces are still operable to 10 GHz (X-band), their electronic controls and drive mechanisms remain intact, and they can be restored to operation as described in this plan.

SSDL plans the following uses for these antennas:

- Tracking and communicating with CubeSats in Low Earth Orbit (LEO) at frequencies of X-band or higher. [Starting 2005-6]
- Tracking and communicating with CubeSats that are changing orbits from LEO to Geosynchronous Transfer Orbit (GTO) to Geosynchronous Orbit (GEO). [Starting 2006-7]
- Tracking and communicating with CubeSats that are on a Moon flyby and return trajectory. [Starting 2008-10]
- Tracking and communicating with CubeSats that may be on orbits beyond the Earth into deep space. [Starting 2008-15]

These 60 foot dish antennas were originally constructed by Professor Ronald N. Bracewell, Director of the Stanford Radio Astronomy Institute (now Stanford's Space, Telecommunications and Radioscience Laboratory, or STAR Lab). Built at a cost of $2 million dollars ($10.5 million in today's dollars), the radio telescope observatory studied numerous extragalactic sources, and was the first to detect the direction of motion of our solar system relative to the cosmic background. Construction was funded by the Air Force Office of Scientific Research and the National Science Foundation.

In support of SSDL research, STAR Lab will oversee the implementation of the satellite tracking ground station upgrades needed, including the satellite tracking control system, drive speed modifications, feed and telecommunication upgrades. The preliminary design work for the upgrades has been completed.

In addition, STAR Lab proposes to enter into an antenna refurbishment and site maintenance agreement with the Friends of the Bracewell Observatory Association (FBOA), a non-profit 501(c)(3) organization, dedicated to the refurbishment and maintenance of Site 515 for the benefit of Stanford University's faculty and students, as well as Stanford's community outreach efforts.

The organization has 58 community volunteers, and will provide STAR Lab, at no charge, the labor, materials, and operating funds necessary to:

- Restore, upgrade, and maintain the antennas and facilities
- Maintain the grounds long-term to prevent dry brush overgrowth to meet fire safety requirements on an on-going basis
- Support the operation of the site for Stanford Satellite Ground Station use, and additional educational uses.
- Maintain liability insurance and hold-harmless agreements to indemnify Stanford for all above activities at the site

An initial $20,000 gift has been made to STAR Lab by supporters of the Friends of the Bracewell Observatory Association which is intended to be applied to the initial restoration of the 1^{st} dish, and its associated satellite tracking upgrades for SSDL missions, building restoration and utilities. FBOA will continue to fund and sustain operations on an on-going basis thereafter.

Back in June of 2004, the University's fire inspector determined that dry brush and vegetative overgrowth at Site 515 presented a fire hazard, and called for its cleanup. The School of Engineering engaged a contractor who has cleared the site of dry brush, plant overgrowth, and debris, and has removed the old dilapidated structures. The five 60 foot dishes themselves are of metal construction on concrete foundations, and were determined by the University Fire Marshall not to be a fire hazard.

In response to a request by STAR Lab and the newly formed Friends of the Bracewell Observatory Association, the School of Engineering decided to delay the demolition of the five 60 foot dishes until after June 30^{th}, 2005, to give interested parties an opportunity to submit proposals for the use of the site. Since carrying out the demolition at this later date was estimated to cost an additional $20,000, STAR Lab placed the $20,000 gift into an account should it be needed for this purpose.

If this plan is accepted, STAR Lab will apply these funds to the above restoration and satellite tracking upgrades for SSDL microsatellite missions. Otherwise, the School of Engineering will use the $20,000 gift to demolish the five 60 foot dishes.

2. Overview: Stanford’s Microsatellite Program at SSDL

With respect to research, Stanford microsatellites designed and built by Stanford’s Space Systems Development Laboratory (SSDL) serve as a generic space-based platform for the variety of low-power, low-volume, and low-mass experiments currently under development. They permit rapid access for state-of-the-art space research and unique opportunities for low-cost payload iteration. Preliminary payload studies include component qualification, environmental monitoring, spacecraft technology, and satellite autonomy experiments. Experiments also include space tether technology that can reduce the cost of space propulsion by moving satellites to higher or lower orbits without expending propellant. Stanford microsatellites are intended to be excellent examples of simple, fast, cheap, flexible and intelligent microsatellite design.

Educationally, the microsatellite program exposes engineering students to spacecraft design by providing hands-on technical and managerial experience in the following areas: conceptual design, requirements formulation, subsystem analysis, detailed design, fabrication, integration, test, launch and operations. Participation emphasizes systems engineering practices and prepares potential advanced engineering and doctoral candidates for the laboratory's more involved engineering and research activities. Designs are technically comprehensive, challenging, and interesting.

Three of SSDL’s microsatellites now in orbit, OPAL, SAPPHIRE, and QuakeSat are briefly described below.

OPAL Mission

Stanford’s OPAL launch
at Vandenberg, California
January 2000

OPAL in orbit

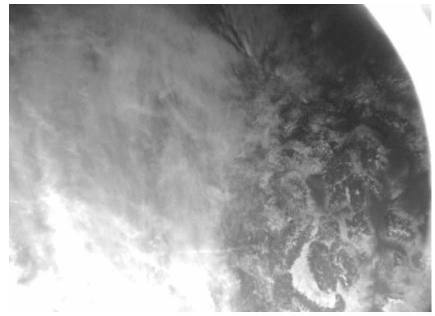
OPAL (Orbiting Picosat Automatic Launcher) was launched on January 2000, on the maiden flight of a Minotaur booster.

OPAL's primary mission was to demonstrate the feasibility of launching multiple picosatellites from a mothership satellite. The satellite's secondary payloads were an accelerometer and magnetometer. OPAL ejected 6 of these smaller satellites into orbit (MEMS 1A, MEMS 1B, STENSAT, MASAT (JAK), Artemis-Thelma, Artemis-Louise).

SAPPHIRE Mission

Stanford's SAPPHIRE launch
at Kodiak, Alaska
September 2001

SAPPHIRE



Earth image from SAPPHIRE in orbit

The SAPPHIRE mission was started at SSDL in early April of 1994, flight-readied in July 1998, and launched on 30 September 2001 as part of the Kodiak Star mission.

SAPPHIRE's primary mission was to space-qualify micromachined infrared sensors. The Principal Investigator was Professor Tom Kenny of Stanford University. These sensors are part of a JPL program to advance the development of light-weight, inexpensive sensors for spacecraft. Also on-board were a digital camera and a voice synthesizer.

CubeSats: QuakeSat and MAST (Space Tether) Missions

The latest generation of micosatellites, known as CubeSats, were designed and developed jointly by Stanford's Space Systems Development Laboratory and California Polytechnic State University. The CubeSat design represents a standardized form factor for small satellites. Cubesats measure just 10cm x 10cm x 10cm in size.

Example of Standard CubeSat

QuakeSat

QuakeSat is a CubeSat developed by SSDL to study earthquake precursor phenomena from space. QuakeSat's primary scientific mission is to detect, record, and downlink Extremely Low Frequency (ELF) magnetic signal data, which may lead to groundbreaking techniques to predict earthquake activity.

Stanford's QUAKESAT launch on
a Eurockot at the
Plesetsk Cosmodrome in Russia
June 2003

QUAKESAT now in orbit

Launched in September, 2003, QuakeSat is a prime example of CubeSat technology, which utilizes commercially-off-the-shelf (COTS) components originally used in non-space applications and using them for scientific experiments and payloads, providing a low cost alternative to launch space missions, and support small-satellite infrastructure in the near future.

MAST (Space Tether) Mission

SSDL and TUI, Inc. have teamed to develop and fly a CubeSat mission known as MAST (Multi-Application Survivable Tether Experiment). This mission will obtain on-orbit measurements of the degradation of space tethers by orbital debris and micrometeorites.

As mentioned earlier, space tether technology is expected to reduce the cost of space propulsion, enabling satellites to move to higher or lower orbits without expending propellant. In addition, tether technology is expected to provide orbital maneuvering and stationkeeping within Low Earth Orbit (LEO); orbital transfer of payloads from LEO to Geosynchronous Orbit (GEO), the Moon, and Mars; and eventually even Earth-to-Orbit (ETO) launch assist.

3. <u>The Need for Additional Ground Station Capacity by SSDL</u>

Stanford's Existing Ground Station for SSDL Missions

Stanford's existing ground station antenna
(on the roof of the Durand Building)
used for the SAPPHIRE mission

In order to support advanced CubeSat missions being planned, SSDL needs greatly increased downlink bandwith capability for higher data transfer, as well as higher ground station sensitivity for increasingly distant orbits and trajectories.

For example, the MAST CubeSat now under development will be transmitting images of the space tether's condition to the ground station, along with GPS and inertial measurements. It is estimated that during a single pass over Stanford, a downlink capacity between 9.4 and 14.5 Mbits will be required.

Unfortunately, the highest data bandwith currently supported by the existing ground station (see photo above of the antenna on the roof of the Durand Building) is 9600 baud, about six times slower than the typical household dial-up internet connection.

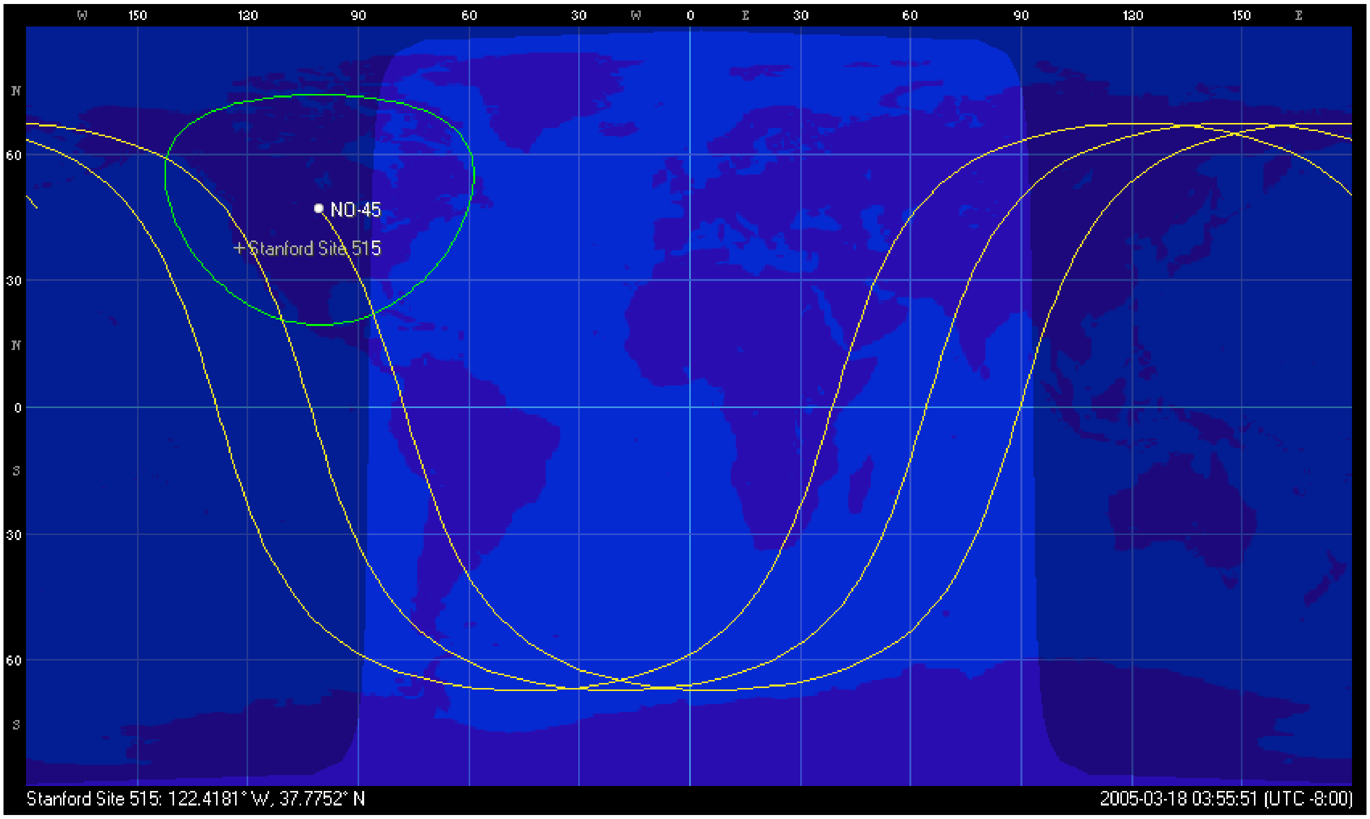
In addition, microsatellites such as OPAL, SAPPHIRE, and QuakeSat (all now in orbit) transmit relatively low power signals at a low frequency (437 Mhz).

For tracking and communicating with planned CubeSats in Low Earth Orbit (LEO) at frequencies of X-band (10 GHz) or higher, high frequency parabolic dishes with diameters on the order of 18 meters (60 feet) or greater would be ideal.

While Stanford's "Big Dish" is in principle large enough (150 feet in diameter), it is unfortunately unusable at these higher frequencies due to the design of its mesh reflector.

On the other hand, the 60 foot diameter dish antennas at Site 515 feature precision solid reflector panels designed for X-band use, and are well suited for high bandwidth communication.

Stanford's Participation in a Multi-University Global Academic Satellite Tracking Network



Above: Stanford's SAPPHIRE microsatellite ground track over Site 515

A single ground station can only track and communicate with a satellite a small fraction of the time (5 to 10 minutes per pass, with 5-6 passes per day), which has placed considerable constraints on the amount of scientific data that can be collected by academic satellites.

To help alleviate this constraint, a Multi-University Global Academic Satellite Tracking Network is now being discussed in the space systems academic community.

The goal of this network is to provide continuous around-the-world satellite tracking coverage for all participating Universities.

By establishing a high-bandwith ground station for SSDL at Site 515, Stanford will be positioned to join, and benefit from, this global tracking network.

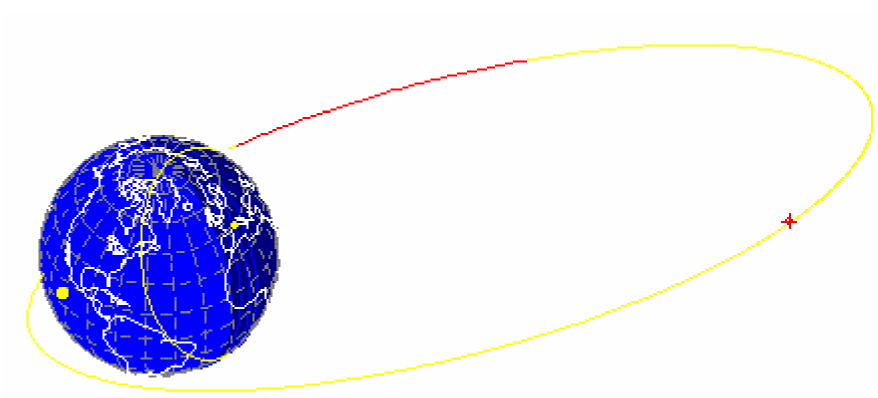
4. Planned uses for existing antennas at Site 515 by SSDL

The Space Systems Development Laboratory is planning a series of CubeSat missions both near-term and long-term, which will be operating at progressively greater distances from the Earth. Below are SSDL's planned uses for the existing antennas at Site 515 in support of these missions:

i. Tracking and communicating with CubeSats in Low Earth Orbit (LEO) at frequencies of X-band or higher. [Starting 2005-6]

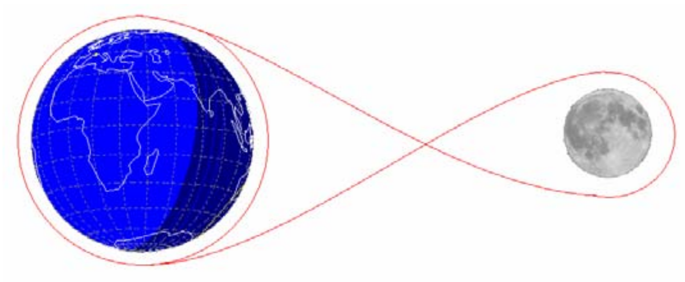
Stanford CubeSat in Low Earth Orbit (LEO)
(Altitude: 200 to 500 miles)

ii. Tracking and communicating with CubeSats that are changing orbits from LEO to Geosynchronous Transfer Orbit (GTO) to Geosynchronous Orbit (GEO). [Starting 2006-7]



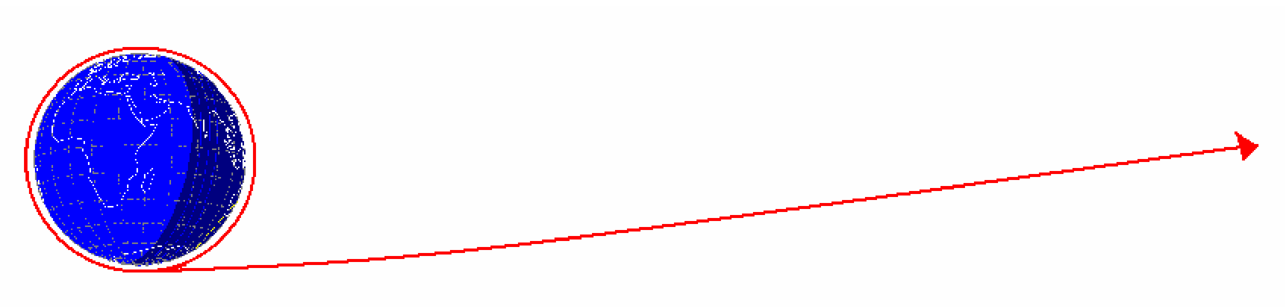
Stanford CubeSat in Geosynchronous Transfer Orbit (GTO)
(Altitude: 22,000 miles)

iii. Tracking and communicating with CubeSats that are on a Moon flyby and return trajectory. [Starting 2008-10]



Stanford CubeSat on Lunar Flyby and Return Trajectory
(Altitude: 250,000 miles)

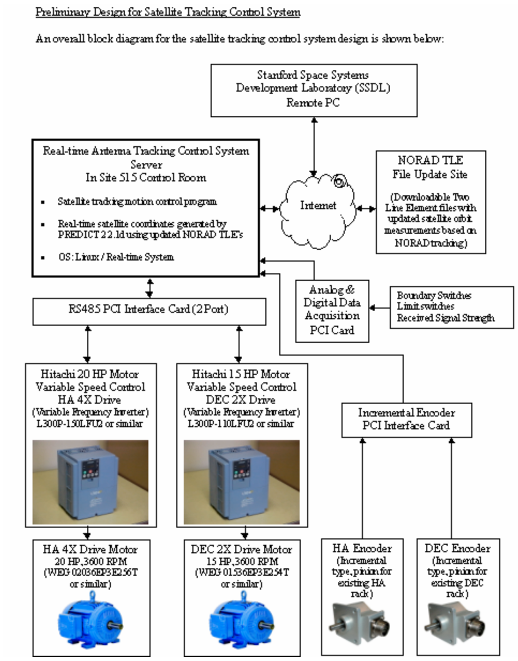
iv. Tracking and communicating with CubeSats that may be on orbits beyond the Earth into deep space. [Starting 2008-15]



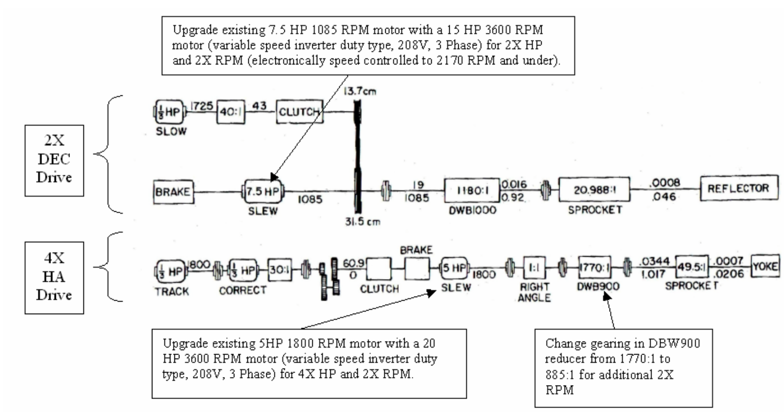
Stanford CubeSat beyond Earth Orbit into Deep Space
(Altitude: Beyond 250,000 miles)

5. Proposed Ground Station Plan for SSDL by STAR Laboratory

STAR Lab will oversee the implementation of satellite tracking ground station upgrades needed by SSDL, including the satellite tracking control system, drive speed modifications, feed and telecommunication upgrades. The preliminary design work has been completed, as illustrated below:



Preliminary Design for Satellite Tracking Control System



Preliminary Design for Drive Speed Modifications

For a complete overview of these designs and associated technical details, please see:

"Appendix B: Preliminary Design for Satellite Tracking Upgrades for Site 515 Antennas"

6. Site 515 Refurbishment and Long-term Maintenance Plan

Expert inspections of Site 515 Antennas and Facilities by FBOA Volunteers

Right-to-left: Kent Price (supervised original construction of the array), Dave Wright (spent 3 years constructing array), Tom Wright (certified welder and machinist), and Lee Pearson (Director, Friends of the Bracewell Observatory Association).

Right-to-left: Kent Price, John Grebenkemper (operated and maintained the array for 7 years), and Dave Wright.

STAR Lab proposes to enter into an antenna refurbishment and site maintenance agreement with the Friends of the Bracewell Observatory Association, a non-profit 501(c)(3) organization, dedicated to the refurbishment and maintenance of Site 515 for the benefit of Stanford University's faculty and students, as well as Stanford's community outreach efforts.

The organization has 58 community volunteers, and will provide STAR Lab, at no charge, the labor, materials, and operating funds necessary to:

- Restore, upgrade, and maintain the antennas and facilities
- Maintain the grounds long-term to prevent dry brush overgrowth to meet fire safety requirements on an on-going basis
- Support the operation of the site for Stanford Satellite Ground Station use, and additional educational uses (see section 7).
- Maintain liability insurance and hold-harmless agreements to indemnify Stanford for all activities at the site

In return, the Friends of the Bracewell Observatory Association's volunteers and supporters will enjoy the satisfaction of:

- Promoting the advancement of research and education through the rescue, refurbishment and maintenance of Site 515 for the benefit of Stanford University's faculty and students, as well as Stanford's community outreach efforts.

- Preserving and presenting the history, technical information, and scientific contributions made at this site.

- Providing experienced volunteer mentors in microwave communication, satellite tracking, and amateur radio astronomy for interested Stanford students, as well as students from local community colleges and high schools.

- Providing supervised access to the dishes (between SSDL passes and missions) for special projects by Stanford University faculty and students, local community college and high school students, and local community organizations that promote the pursuit of science and engineering education.

- Providing supervised radio telescope viewing of celestial objects by Stanford faculty, students, and members of the local community by appointment.

An initial $20,000 gift has been made to STAR Lab by supporters of the Friends of the Bracewell Observatory Association which is intended to be applied to the initial restoration of the 1st dish, and its associated satellite tracking upgrades for SSDL missions, building restoration and utilities for the first three quarters (please see the Funding Plan section for details). FBOA will continue to fund and sustain operations on an on-going basis thereafter.

To view the agreement document, please see:

"Appendix C: STAR Lab Antenna Refurbishment and Site Maintenance Agreement "

7. Additional Educational Uses Between SSDL Satellite Passes and Missions

In addition to the educational uses described in section 6 above, Professor Dave Leeson proposes the following uses for his classes:

[Insert Dave Leeson's outline here]

8. History of Stanford Field Site 515 (Heliopolis)

The Stanford 32-Element Cross Interferometer at Heliopolis (Site 515), circa 1972.

In 1955 Professor Ronald N. Bracewell, Director of the Stanford Radio Astronomy Institute (now known as STAR Lab), began the design and construction of a 9.1 cm microwave spectroheliograph consisting of 32 ten-foot dish antennas in a cross-shaped array at "Heliopolis" (now known as Stanford Field Site 515).

Funded by the Air Force Office of Scientific Research, the array produced 11 years of detailed daily maps of the face of the sun in a virtually unbroken sequence from 1962 to 1973, completing one full solar cycle, and was the first radio telescope to achieve the resolution of the human eye.

The National Oceanic and Atmospheric Administration (NOAA) widely disseminated these solar map observations in their Solar Geophysical Data Bulletins.

NASA relied on these daily reports during the Apollo lunar missions for solar flare predictions to help the astronauts avoid potentially lethal radiation exposure.

In addition, timely information about major solar flares was of immediate worldwide importance, as such events are capable of disrupting communications and shutting down power grids.

This research also advanced the state of the art in medical diagnosis. The image reconstruction mathematical methods developed by Professor Bracewell for this array were universally adopted into the algorithms of CAT Scanners. For this contribution, Professor Bracewell was elected to the National Academy of Sciences' Institute of Medicine.

Although the 32 dishes were dismantled after 1973, their historical concrete mounting piers remain, bearing the signatures of many famous radio astronomers:

Many of the remaining dish support piers bear the chiseled signatures of famous radio astronomers, including J.G. Bolton, who discovered the first four radio stars. Over 180 historical autographs were carved by distinguished visitors during the past 50 years.

The Stanford Five Element Array, consisting of five 60-foot dishes, combiner building, and control room, circa 1972.

By 1966 Professor Bracewell had begun the construction of a much larger imaging radio telescope, capable of studying the structure, movement, and polarization of extragalactic sources at high resolution, known as the Stanford Five Element Array. The system consists of five 60-foot diameter dish antennas arranged in a minimum-redundancy array, and uses the principle of fast earth rotation synthesis to create high resolution image maps of the sky at a wavelength of 2.8 cm (10.7 Ghz).

The array was designed and built from 1966 through 1972, by the Stanford Radio Astronomy Institute (now STAR Lab) at a cost of $2 million dollars ($10.5 million in 2005 dollars), and was funded by the Air Force Office of Scientific Research and the National Science Foundation.

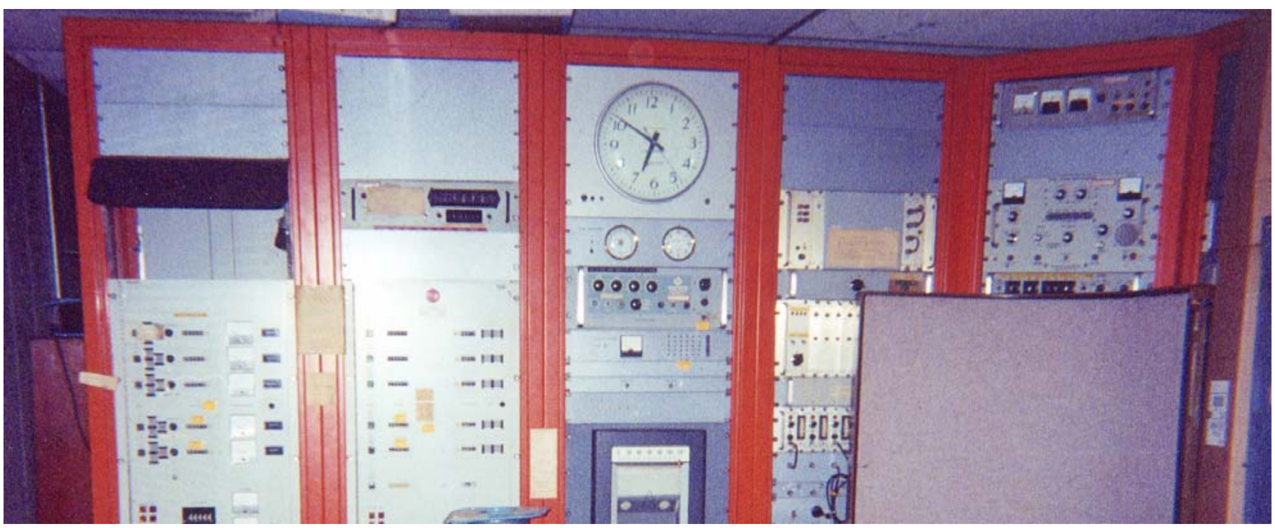
One of the most important discoveries made by this telescope was establishing the direction of motion of our solar system relative to the cosmic background.

In addition, the angular diameters, temperatures, and polarizations of numerous cosmic sources were studied, including radio galaxies, supernova remnants, planetary nebula, and H II hydrogen cloud regions.

Both extragalactic and solar activity observations were conducted until 1979, when the array was turned off due to lack of funds.

In 2004 and 2005, expert inspections were conducted by the original builders of the array in order to provide the basis for this restoration plan. A brief overview of their findings can be seen in the photo descriptions below:

The array today*: expert inspection reveals that all five 60 foot dishes are structurally sound, their surfaces are still operable to 10 GHz (X-band), and their drive mechanisms remain fully intact. The surface grime easily washes away, revealing bright white enamel finish panel surfaces. The rust is superficial, and can be removed and repainted.*



The control room (Butler building) metal roof and electronic systems are fully intact. Several racks of equipment powered up successfully as recently as last year.

The delay line shelter (cinder block structure) has a roof leak, which can be repaired. Electronic systems in the shelter appear in good shape, and a third of the antenna cables actually maintained their dry nitrogen pressurization for 25 years. Inspectors repressurized all cables to 15 PSI and verified their integrity.

Based on these findings, it was determined that the array can be restored to operation as put forth in this plan.

For detailed inspection report findings about the current condition of the array and associated buildings, please see:

"Appendix A: Inspection Report Summary for Antenna Array, Control Room, and Delay Line Shelter"

9. Personnel

Director, Site 515 Stanford Satellite Tracking Upgrade Project:

- Professor Umran Inan, Director, Space, Telecommunications and Radioscience (STAR) Laboratory

Director, SSDL Satellite Operations:

- Professor Robert Twiggs, Director, Space Systems Development Laboratory

Volunteer Team Supervisor, Site 515 Stanford Satellite Tracking Upgrade Project:

- Robert Lash, M.D, President, Friends of the Bracewell Observatory Association (FBOA)

Volunteer Technical Leads for Site 515 Stanford Satellite Tracking Upgrade Project (FBOA):

Restoration and Upgrade Team Lead

- Kent Price, Loral Space Systems, supervised the original design, construction and operation of the Site 515 Array

Ground Station Design Lead

- Judd Reed, designed and implemented the TIROS-n Satellite Ground Station for USGS Earth Resources Observation Center

Mechanical Systems Lead

- Dave Wright, spent 3 years constructing the array at site 515

Electronic Systems Lead

- John Grebenkemper, operated and maintained the Site 515 array electronics for 7 years

Software Lead

- Tomas Wilson, former software engineer for the National Radio Astronomy Observatory (NRAO) at the Very Large Array (VLA) radio telescope

Document Preservation and Archiving Lead

- Chris Ridder, intellectual property lawyer and former journalist

Facilities Lead

- Jim Knapp, professional facilities and electrical systems consultant

Volunteer Team for Site 515 Restoration and Maintenance (FBOA):

1. Al Graf
2. Alan Marote
3. Andrew Tubbiolo
4. Art Lange
5. Ben Koning
6. Bob Lash
7. Bryan Embrey
8. Chris Dapples
9. Chris Ridder
10. Craig Fleming
11. Dave Ocame
12. Dave Wright
13. David Fields
14. Dick Crane
15. Don Latham
16. Ed Hess
17. Eliot Lash
18. Fred Dietrich
19. George Martin
20. Ismail Haugabook
21. Jamie Elsila
22. Jeff Lichtman
23. Jim Knapp
24. Jim McDonald
25. Jim Moss
26. John Grebenkemper
27. John Marcus
28. Judd Reed
29. Kalyan Dutta
30. Karen Jensen
31. Kent Price
32. Keri Kukral
33. Kevin Finley
34. Kim Hay
35. Laura Langland-Shula
36. Lee Courtney
37. Lee Pearson
38. Leon Chrisman
39. Leonard Tramiel
40. Lon Radin
41. Mark Bracewell
42. Mark Lawrence
43. Matt Ettus
44. Michael Helms
45. Michael Hudson
46. Mike Fox
47. Mike Gustafson
48. Mike McNeil
49. Pete Garcia
50. Phillip Lamb
51. Robert Muller
52. Ron Abileah
53. Stacy Jo McDermott
54. Stu Hansen
55. Tim Carlson
56. Tom Wilson
57. Tom Wright
58. Wendie Bernstein Lash

10. <u>Timeline</u>

		2005				2006			
		Q1 '05	**Q2 '05**	**Q3 '05**	**Q4 '05**	**Q1 '06**	**Q2 '06**	**Q3 '06**	**Q4 '06**
Assemble Core Restoration Team		**DONE**							
Conduct Expert Inspections		**DONE**							
Complete Final Proposal		**DONE**							
Proposal Review and Acceptance			**XXXX**						
Restoration of 1st Dish				**XXXX**	**XXXX**	**XXXX**	**XXXX**		
Building Restoration				**XXXX**	**XXXX**				
Satellite Tracking Upgrades for SSDL				**XXXX**	**XXXX**	**XXXX**			
Commence Satellite Tracking Operations for SSDL								**XXXX**	**XXXX**
Educational Community Outreach Support								**XXXX**	**XXXX**

11. Funding Plan

An initial $20,000 gift has been made to STAR Lab by supporters of the Friends of the Bracewell Observatory Association which is intended to be applied to the initial restoration of the 1st dish, and its associated satellite tracking upgrades for SSDL missions, building restoration and utilities for the first three quarters.

Additional operational funding (estimated at $11,000 for 2005, and $20,000 in 2006) will be provided by the Friends of the Bracewell Observatory Association, which will continue to fund and sustain operations on an on-going basis thereafter under the terms of the STAR Lab maintenance agreement (for further details please see: “Appendix C: STAR Lab Antenna Refurbishment and Site Maintenance Agreement”).

In addition, labor and materials required to carry out the plan will be provided by volunteers of the Friends of the Bracewell Association at no cost to Stanford.

The planned 2 year budget is shown below:

Site 515 Restoration and Upgrade 2 YR Budget								
DRAFT, Updated 1/16/05	**2005**				**2006**			
	Q1 '05	Q2 '05	Q3 '05	Q4 '05	Q1 '06	Q2 '06	Q3 '06	Q4 '06
Revenue								
STAR Lab Site 515 Restoration Fund	20,000							
Gifts / Friends of the Bracewell Obs. Assoc.	500	500	5000	5000	5000	5000	5000	5000
Annual Revenue Totals				**$31,000**				**$20,000**
Expenses								
Utilities	0	0	600	600	1200	1200	1200	1200
Phone/Connectivity	0	0	300	300	300	300	300	300
Liability Insurance	0	0	500	500	500	500	500	500
1st Dish Restoration / Materials and Equip.Rentals	0	0	2500	2500	2500	0	0	0
Satellite Tracking Upgrades	0	0	10000	0	0	0	0	0
Control Room and Combiner Bldg Restoration	0	0	5000	5000	0	0	0	0
Educational Community Outreach Support	0	0	0	0	0	0	2500	2500
Quarterly Expense Totals	$0	$0	$18,900	$8,900	$4,500	$2,000	$4,500	$4,500
Annual Expense Totals				**$27,800**				**$15,500**
Annual Net				**$3,200**				**$4,500**
Ending Cash Reserve				*$3,200*				*$7,700*

12. Appendices

Appendix A: Inspection Report Summary for Antenna Array, Control Room, and Delay Line Shelter

Appendix B: Preliminary Design for Satellite Tracking Upgrades for Site 515 Antennas

Appendix C: STAR Lab Antenna Refurbishment and Site Maintenance Agreement

Appendix A

Inspection Report Summary for Site 515 Antenna Array, Control Room, and Delay Line Shelter

Overview

With the permission of Stanford's School of Engineering, a series of expert inspections were recently conducted at Site 515 which determined the current condition of the antenna array and facilities. These inspections provided the basis for the restoration and upgrade plans in this proposal.

The expert inspection team included:

- Professor Ronald N. Bracewell, who led the design, construction, and operation of the antennas and facilities at Site 515 since its inception.
- Kent Price, Loral Space Systems, who supervised the original construction of the Site 515 antenna array and worked closely with Prof. Bracewell throughout its operation.
- Dave Wright, who worked on constructing the Site 515 antennas for 3 years
- Tom Wright, a certified welder and machinist
- John Grebenkemper, who operated and maintained the Site 515 systems for 7 years. He was involved in the Site 515 electronics and wrote much of the software.
- Kalyan Dutta, who originally analyzed the strength of the Site 515 antenna support structures under wind loading
- Jim Knapp, professional facilities and electrical systems consultant

Below is a summary of the inspection findings:

Antenna Array

- Dish panel surfaces are intact, and still good to 10 GHz
- Mounts are structurally sound, and all key parts are still there
- Surface rust is superficial, and can be removed and re-painted
- System electronics are intact and can be refurbished

- Surface grime easily washes away, revealing beautiful white enameled aluminum panel surfaces
- Hour Angle (east-west movement) drive components are intact

Expert inspection of an Hour Angle drive

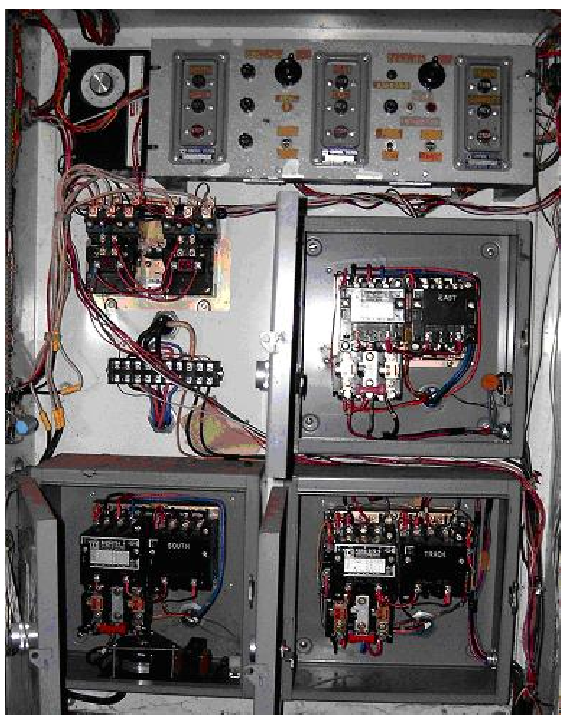
Right-to-left: Kent Price (supervised original construction of the array), Dave Wright (spent 3 years constructing array), Tom Wright (certified welder and machinist), and Lee Pearson (Director, Friends of the Bracewell Observatory Association)

- Declination (north-south movement) drive components are intact

Expert inspection of a Declination drive

Right-to-left: John Grebenkemper (operated and maintained the array for 7 years) and Dave Wright (spent 3 years constructing array)

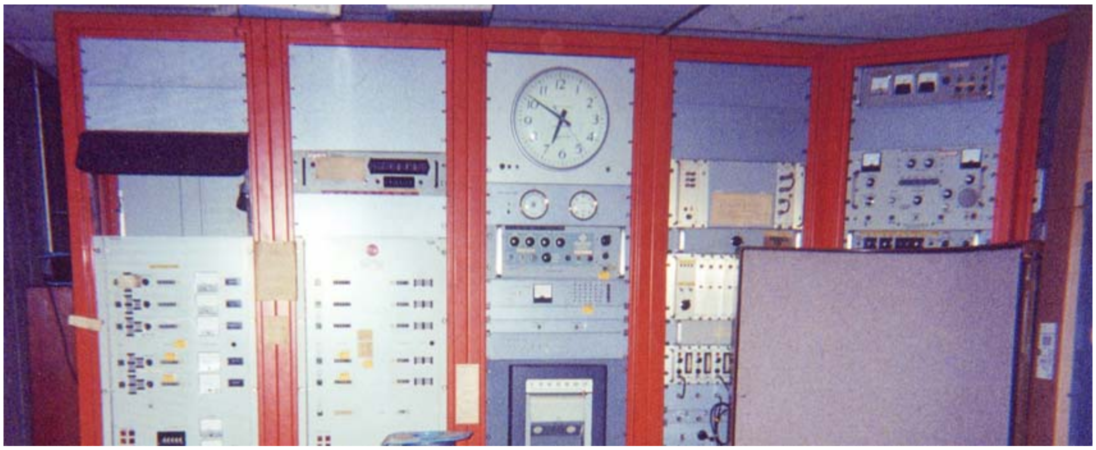
- Electrical contactor boxes for local and remote control of the movement of each dish appear in excellent condition:



Inspection of an electrical contactor box (one per dish) reveals that all components remain in excellent condition

Control Room

- Control room (Butler building) metal roof and electronic systems are intact. Several racks of equipment powered up successfully as recently as last year.



Control room equipment was found to be in excellent condition

Delay Line Shelter

- Delay line shelter has a roof leak, but we are protecting the equipment with a tarp. Electronic systems appear in good shape, and a third of the antenna cables have actually maintained their nitrogen pressurization for 25 years. We repressurized all cables to 15 PSI to verify their integrity.

Delay line shelter electrical wiring and antenna cables were found to be in good shape

Site 515 Grounds

- Dry brush, vegetative overgrowth, and old debris were cleared from site by Stanford's School of Engineering to meet fire code safety requirements.

- Old dilapidated structures have been demolished and removed (Old Factory Building and Quonset Hut).

The old dilapidated Factory Building and Quonset Hut have been removed and the debris have been cleared.

The detailed array inspection checklist and findings are attached below.

5-Element Array Check List

	A	B	C	D	E	F	G	H	I	J	K
1								Antenna			
2		Item		Number		Primo	Secundo	Tertio	Septimo	Decimo	Comments
3											
4	Electric substation (west of Butler Building)										
5											
6	Butler Building (control center)										
7											
8	Delay Line building (24' x 16', 30" roof overhang)										
9		Array drive power circuit breakers									
10			Main circuit breaker								
11			Auxiliary power (top left of main circuit breaker)								
12		Pressure gauges for 7/8" pressured LO cables		13							
13		Cables from Delay to Butler Buildings									
14			LO cables (7/8" spiroline, 160 ft long)		2						2.6725 GHz LO reference; Butler to 5 antennas
15			Spares (7/8" spiroline, 160 ft long)		1						
16			IF cables (1/2" spiroline, 187 ft long)		5						1 to 100 MHz IF, antennas to Butler
17		Cables from Antennas to Delay Buildings									
18			LO cable (7/8" spiroline, 330-380 ft long)		5						2.6725 GHz LO reference; Butler to 5 antennas
19			Spare (7/8" spiroline, 327-378 ft long)		5						
20			IF cable (1/2" spiroline, 380-390 ft long)		1						1 to 100 MHz IF, antennas to Butler
21											
22	Ground feed box (near Pedestal S leg)										
23		Electric light on top									All are broken or missing
24		Fire extinguisher mounted on outside									Boxes OK, extinguishers & glass missing
25		Horn translator									
26		Main power supply									
27		Stabiline regulated power supply									
28											
29	RF cable run (at S leg)										
30		LO cable, ground to polar axle									
31		Rotary joint at polar axle									
32		E-W trench for RF (south of foundation)									
33											
34	Contactor box (near Pedestal W leg)										
35		Conduit to electrical trench						tree root			
36		E-W trench for electrical (north of foundation)									
37											
38	Survey stand on Pedestal S leg										Covers missing, brass plates OK
39											
40	Hour angle drive machinery (ground level)										
41		Drive motor mounting plate on foundation		1							
42			Corrugated iron cover over plate		1						
43			Tracking motor, 1/3 HP, 1800 rpm		1						
44			Flexible coupling		1						
45			Correcting motor, 1/3 HP, 1800 rpm		1						
46			Right angle reducer, 30-1		1						
47			Flexible coupling		1						
48			Tracking gear box (60 rpm in, 60.9 out)		1						
49			Shaft rpm: 60.9 track, 0.0 slew								
50			Clutch		1						
51			Brake		1						
52			Slew motor, 5 HP, 1800 rpm		1						
53			Flexible coupling		1						
54			Right angle, 1-1		1						
55			Flexible coupling		1						
56			Gear reducer, DWB900, 1770-1		1						
57			Flexible coupling		1						
58			Sprocket rpm: 0.0344 track, 1.1017 slew								
59		Drive sprocket mounting box (on foundation)		1							
60			Drive sprocket shaft		1						
61			Pillow blocks for drive shaft		2						
62			Idler shafts		2						
63			Pillow blocks for idler shafts		4						
64			Drive sprocket, ?? teeth		1						
65			Idler sprockets, ?? Teeth		2						
66			Sprocket-wheel drive ratio: 49.5 - 1								
67		Hour angle chain (on 15-ft radius)		1							Rusted at exposed ends
68			RC-140-3 chain, 48-ft		1						
69			Chain anchors		2						
70			Special anchor pins		2						
71			Chain tension elastomer		2						
72			Elastomer housing assembly		2						
73			Chain end support assembly		2						
74			Chain repair kit		1						Does not exist
75			HA drive rpm: 0.0007 track, 0.0206 slew								Tracks at sidereal rate
76		Position readout box (hour angle)		1							
77			Position readout rack on yoke (48 ft)		2	loose (w)					
78			Pinion		1						
79			Synchro transmitter		1						
80			Synchro mounting bracket		1						
81			(6 conductor cable to control/ display)		1						
82			East-West limit switches		?						

	A	B	C	D	E	F	G	H	I	J	K
1								Antenna			
2		Item		Number		Primo	Secundo	Tertio	Septimo	Decimo	Comments
83											
84	Pedestal										
85		Hour angle (yoke) bearings		1							
86			Top bearing		1						
87			Bottom bearing		1						
88		Hub-pedestal stow latch		1							
89			Elastomer shock pads		2						
90			Latch piece		1						
91			Stow sensor switches								
92			Mounting brackets and guides								
93			Air cylinders		1						Replacements needed
94			Air pipe to ground								
95			(Air pipe to tank / control)								
96											
97	Yoke assembly										
98		Declination bearing		2							Rusted at exposed ends
99			East declination bearing		1						
100			West declination bearing		1						
101		Declination drive		1							
102			Mounting plate		3						
103			Slow motor, 1/3 HP, 1725 rpm		1						
104			Reducer, 40:1		1						
105			Clutch		1						
106			Pulley wheel, 13.7 cm		1						
107			Fan belt		1						
108			Brake (for slew motor)		1						
109			Slew motor, 7.5 HP, 1085 rpm		1						
110			Pulley wheel, 31.5 cm		1						
111			Flexible coupling; 19/ 1085 rpm slow/slew		1						
112			Shaft rpm: 19 track, 1085 slew								
113			Flexible coupling		1						
114			Gear reducer, DWB1000, 1180:1		1						
115			Flexible coupling		1						
116			Shaft rpm: 0.016 track, 0.92 slew								
117			Drive shaft		1						
118			Pillow blocks for drive shaft		2						
119			Idler shafts		2						
120			Pillow blocks for idler shafts		4						
121			Drive sprocket, 16-tooth		1						
122			Idler sprockets, 16-tooth		2						
123			Sprocket-wheel drive ratio: 20.988:1		3						
124		Chain and support assembly (declination)									Chain wraps around declination wheel
125			RC-120-6 chain, 24-ft								
126			Chain anchors								
127			Special anchor pins								
128			Chain tension elastomer								
129			Elastomer housing assembly								
130			Chain repair kit								Does not exist
131		Position readout system (declination)		1							
132			Position readout rack (on decl wheel)		1						24 feet long
133			Pinion								
134			Encoder								
135			Encoder mounting bracket								
136			(54 wire cable to control/ display)								
137			North-South limit indicators								
138		Polar axle									
139			(Bearings are part of pedestal)								
140		Rotary joints for RF cable (hour angle axis)				loose (w)					
141											
142	Reflector										
143		Declination wheel axle									
144			East bearing								
145			West bearing								
146		Rotary joints for RF cable (declination axis)				loose (w)					
147		Hub									
148		Dish									
149			Outside panels	56				Bent			
150			Center panels								
151		Feed support									
152			RF cables								
153			Electrical cables								
154		Feed box		1							
155			Feed rotator gears and bearing		1						
156			Stepper motor		1						
157			Encoder		1						

	A	B	C	D	E	F	G	H	I	J	K
1								**Antenna**			
2		Unit		Action	Frequency	Primo	Secundo	Tertio	Septimo	Decimo	Comments
3	**Hour angle drive**										
4		All		Derust, LPS 3	1 month						
5		Track motor		Grease B	10 year						
6		Coupling		Grease A	6 month						
7		Correct motor		Grease B	10 year						
8		Dodge reducer		Oil C	6 month						
9				Change oil	2 year						
10		Coupling		Grease A	6 month						
11		Change gears		Oil C	1 month						
12				Change oil	1 year						
13		Sleeve bearings		Grease A	1 month						
14		Clutch		Adjustment	1 month						
15		Slew motor		Grease B	10 year						
16				Check brake	1 year						
17		Coupling		Grease A	6 month						
18				Tighten flange bolts							
19		Right angle unit		Oil B	1 month						
20				Change oil	2 year						
21		Coupling		Grease A	6 month						
22				Tighten flange bolts							
23		Link Belt reducer		Grease B	1 month						
24				Oil C	6 month						
25				Change oil	2 year						
26				Check heaters	6 month						
27		Coupling		Grease A	6 month						
28				Tighten flange bolts							
29		Sleeve bearings		Grease A	1 month						
30		Sprockets		LPS 3	1 month						
31				Check alignment							
32		Chain		LPS 3	3 month						
33				Remove, oil E	3 year						
34		Polar bearings		Grease A	3 month						
35		Limit/boundary switches		Check stops	6 month						
36		Drive track motor		Move antenna	1 month						
37		Drive correct motor		Move antenna	1 month						
38		Drive slew motor		Move antenna	1 month						
39	**Declination drive**										
40		All		Derust, LPS 3	1 month						
41		Slew motor		Grease B	10 year						
42				Check brake	1 year						
43		Sheaves		Check tight	6 month						
44		Vee belt		Check tension	1 month						
45		Clutch		Check	6 month						
46		Slow gear motor		Motor grease B	10 year						
47				Oil B	6 month						
48				Change oil	2 year						
49		Coupling		Grease A	6 month						
50				Tighten flange bolts							
51		Link Belt reducer		Grease B	1 month						
52				Oil C	6 month						
53				Change oil	2 year						
54				Check heaters	6 month						
55		Coupling		Grease A	6 month						
56				Tighten flange bolts							
57		Sleeve bearings		Grease A	1 month						
58		Sprockets		LPS 3	1 month						
59				Check alignment							
60		Chain		LPS 3	3 month						
61				Remove, oil E	3 year						
62		Declination bearings		Grease A	3 month						
63		Limit/boundary switches		Check stops	6 month						
64		Drive track motor		Move antenna	1 month						
65		Drive slew motor		Move antenna	1 month						
66											
67											
68											
69											

Maintenance Schedule

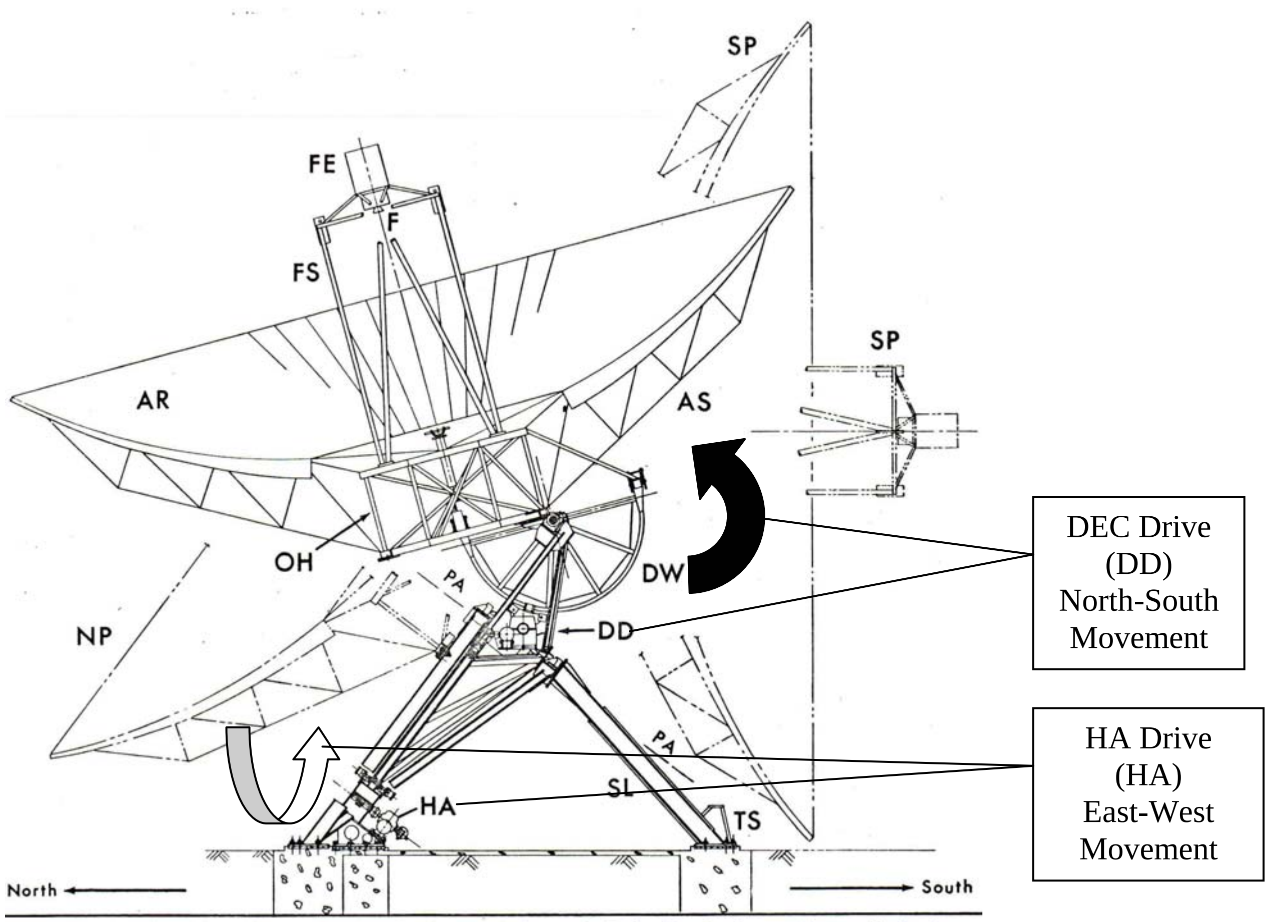
	A	B	C	D	E	F	G	H	I	J	K
1								Antenna			
2		Unit		Action	Frequency	Primo	Secundo	Tertio	Septimo	Decimo	Comments
70	**General**										
71		All		Paint	1 month						As required
72		Intercom		Check	1 month						
73		Cables		Wear and damage	1 month						
74		Antenna lights		Check	1 month						
75		Night lights		Check	1 month						
76		Cable pressure		N2 at 20 psi	1 month						
77		Decimo airline		Bleed	6 month						
78		Air line water trap		Empty	6 month						
79		Stow latch									
80			Check clearances	Adjust as required	1 month						
81			Stow latch	Grease A	1 month						
82			Air cylinder	LPS 3	1 month						
83			Air line oilers	Oil B	3 month						
84			Filters	Clean	3 month						
85											
86											
87	**Notes**										
88	1.	Reference, Glint 468, 3/17/1972. Proposed maintenance schedule									
89	2.	Grease reference									
90		A	(HA drive) Union: Unoba F-2 multipurpose (white)								
91		B	(declination drive) Mobile: Mobilux No. 2								
92	3.	Oil reference									
93		B	Union heavy duty motor oil SAE 50 (AGMA 3)								
94		C	Union gear compound 130 (AGMA No. 7 EP)								
95		D	Union gear compound 165 (AGMA No. 8 EP)								
96		E	Shell: Ensis compound 352 (east coast) (Shell code no. 73500)								
97	4.	Maintenance records were kept from 6/1/72 to 9/1/73 by Carl Crisp									
98											

Appendix B

Preliminary Design for Satellite Tracking Upgrades for Site 515 Antennas

Overview of Existing Antenna Drive System

The existing antenna drive system was designed for tracking of celestial objects, and is also capable of slewing at higher speeds for setting up observations, as well as moving the dish to its stow position during high wind conditions. The declination (DEC) drive can move the antenna in a continuous north-south arc, from its stow position pointing to the North Star (Polaris, at +90 deg DEC) to the southern horizon. The hour angle (HA) drive can move the antenna in a continuous east-west arc horizon-to-horizon. The location of these drives and their effect on dish movement are shown in the diagram below:



A scale drawing of a 60-foot reflector with the following principal parts labeled: *AR*, aluminum reflector; *AS*, aluminum structure; *DD*, declination drive; *DW*, declination wheel (steel); *F*, focus; *FE*, front-end box; *FS*, feed support (steel); *HA*, hour-angle drive; *NP*, north-pole-pointing (stow) position; *OH*, octagonal hub (steel); *PA*, polar axis; *SP*, service position; *SL*, south leg; *TS*, theodolite stand (for polar alignment). Stanford Radio Astronomy Institute diagram.

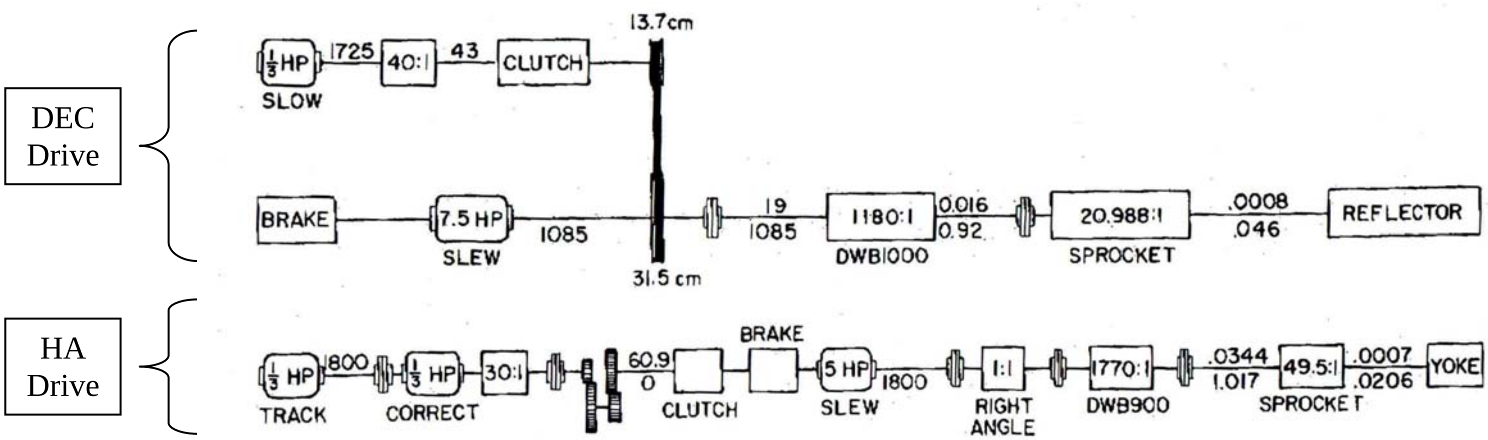
Existing Declination (DEC) and Hour Angle (HA) Drives

Based on the schematic below for the existing drives, we can see that the fastest speeds currently produced when slewing are:

DEC drive current max speed (“1X”) = .046 RPM (= 16.5 degrees per minute in north-south movement)

HA dive current max speed (“1X”) = .0206 RPM (=7.5 degrees per minute in east-west movement)

For simplicity, we will refer these speeds as the “1X” speeds for DEC and HA respectively.

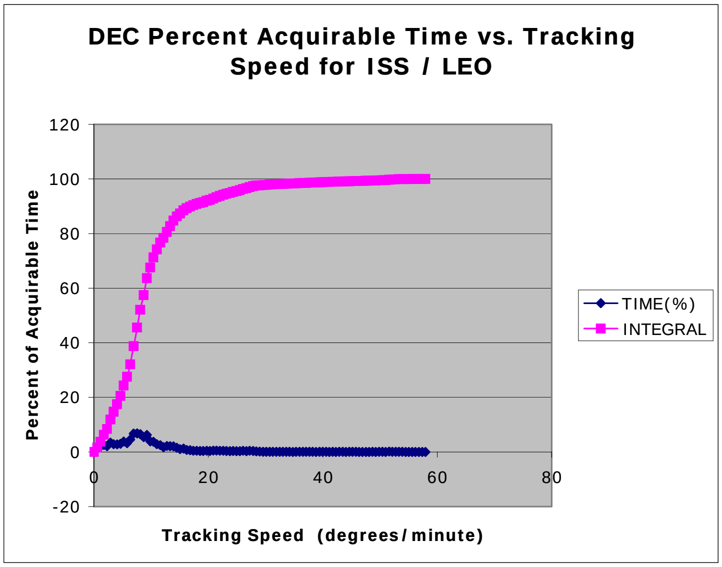


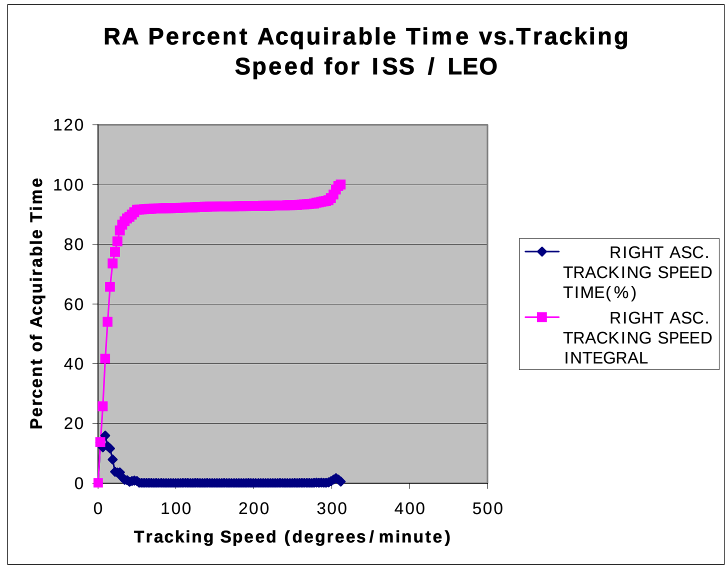
Schematic for Existing Declination (DEC) and Hour Angle (HA) Drive Trains

(Note: The numbers shown above are in RPM units. The RPM values shown above the shaft lines are for the DEC slow and HA track/correct modes, and the RPM values below the shaft line are for high speed slew mode).

Tracking Speed Increase Requirements for Low Earth Orbit (LEO) Satellites

To determine the tracking speed increases needed for Stanford CubeSats in low earth orbit (LEO), we ran simulations for 1000 visible passes over Stanford corresponding to a 6 month tracking period. The percent acquirable time as a function of tracking speed was then plotted for each drive:





Percent acquirable time as a function of tracking speed for the DEC and RA drives for Stanford CubeSats in Low Earth Orbit

Based on the above curves, we can summarize the effect of a range of possible speed increases (1X through 10X) on percent acquirable time as follows:

	1X	**2X**	3X	**4X**	5X	10X
DEC Drive	89%	**[98%]**	99%	100%	100%	100%
HA Drive	30%	65%	77%	**[85%]**	88%	92%

Now, if we apply the criteria that we would like to be able to view the satellite about 85% of the time on average for all visible passes, we therefore need to increase the speed of the **HA drive by 4X**, and increase the speed of the **DEC drive by 2X**.

This gives us:

HA (at 4X) = 30 degrees per minute
DEC (at 2X) = 33 degrees per minute

Note that the 85% figure is best case, as any obstructions near the horizon may limit the actual viewable arc.

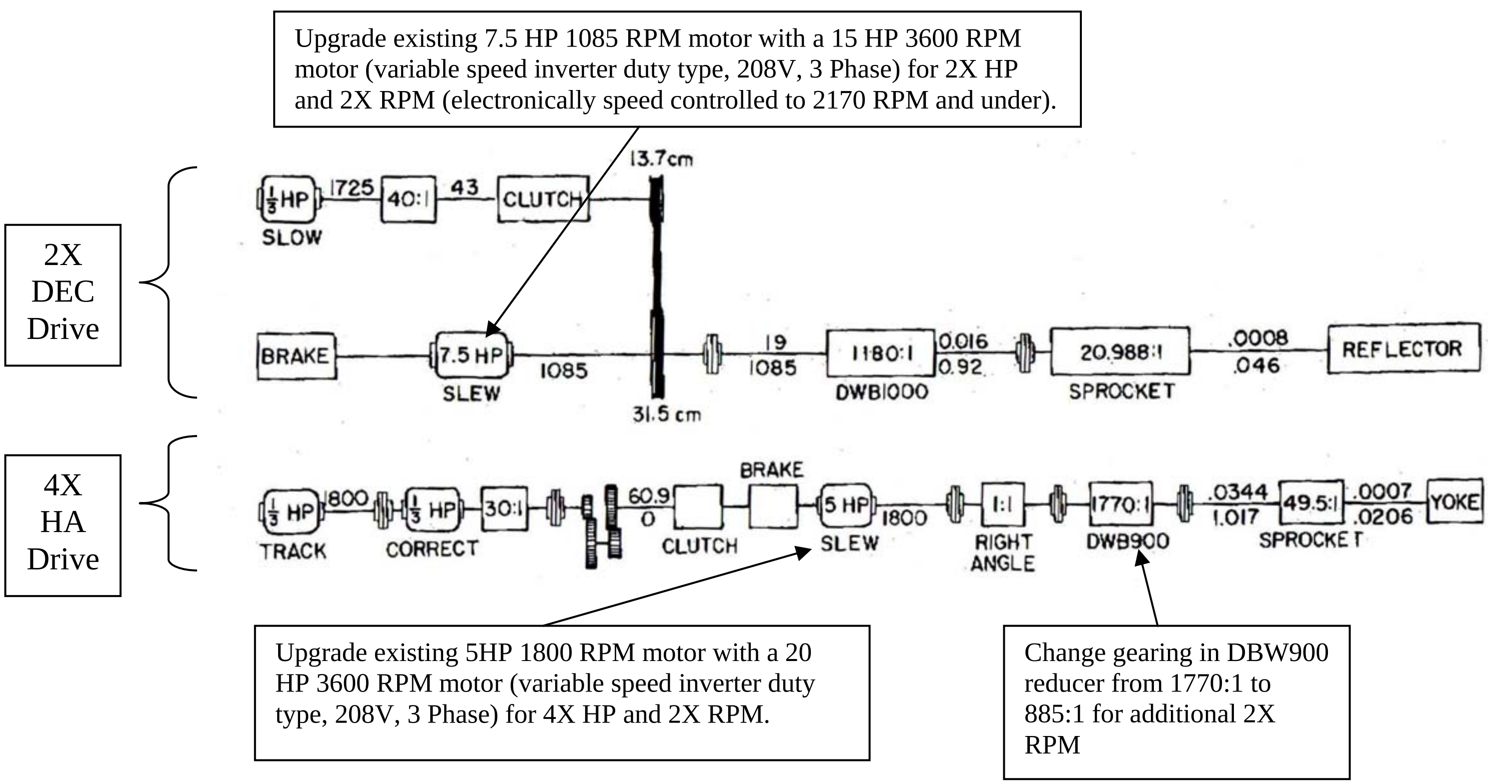
Tracking Speed Increase Requirements for Geosynchronous Transfer Orbit (GTO), Geosynchronous Orbit (GEO), Lunar Flyby, and Deep Space Mission Satellites

The tracking speed requirements for these orbits and trajectories are less than for Low Earth Orbit (LEO) satellites, and therefore will be satisfied with the proposed speed increase for LEO.

In the case of GTO orbits, even though the dish will need to reverse its movement to follow a retrograde loop at apogee, the actual speed needed at that time will be quite low.

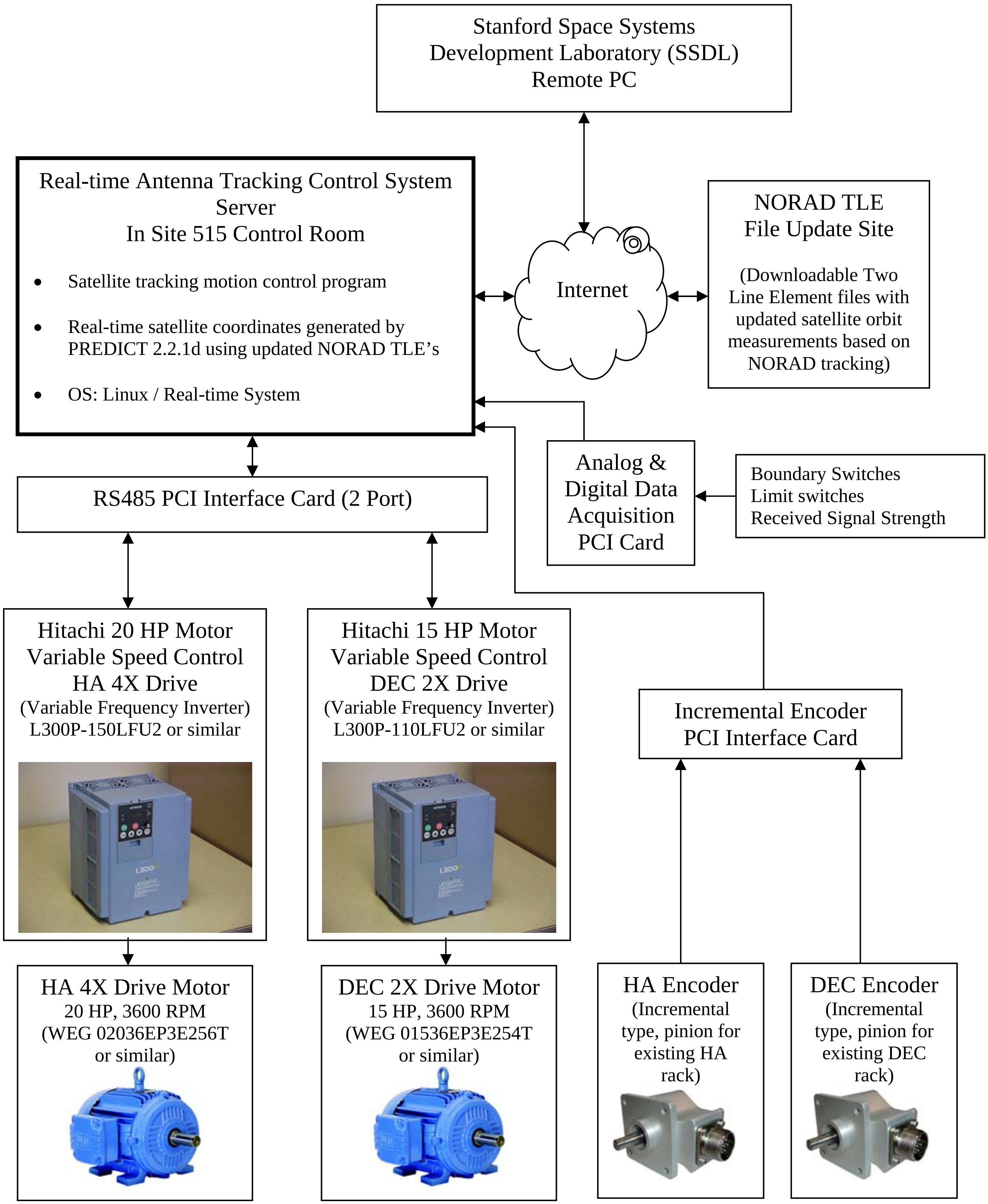
Tracking Speed Upgrade Modifications

To achieve a 2X speed increase in DEC, and a 4X speed increase in HA, the following upgrades are proposed:



Preliminary Design for Satellite Tracking Control System

An overall block diagram for the satellite tracking control system design is shown below:



As illustrated above, the satellite tracking and antenna motion control functions are handled by a real-time antenna tracking control server in the existing Site 515 Control Room. To achieve robust performance at low cost, the Satellite Tracking and Motion Control Program will be running on an Intel-based PC running a real-time variant of the Linux operating system.

The Motion Control program will obtain real-time satellite coordinates by calling PREDICT 2.2.1d, a widely used open-source satellite tracking program that generates real-time ALT-AZ coordinates for driving telescope motion control systems. PREDICT 2.2.1d generates its coordinates using updated NORAD Two Line Element (TLE) orbital description files. A UNIX CRON job running on the server will automatically download the most recently updated TLE files at regular intervals from a NORAD Internet mirror.

Based on the actual antenna position measured by incremental encoders, and the desired antenna position derived from the real-time satellite coordinates, the Motion Control program will servo the HA and DEC drive motors to minimize the positional difference, using standard closed-loop control methods. Motor acceleration/deceleration rates will be controlled to maintain impulse forces within original design (1X) limits.

As an added enhancement, once the antenna is tracking, the Motion Control system will measure the satellite's received signal strength, and "wobble" the beam in small (1/4 beamwidth) offsets to fine-tune the positioning for maximum signal strength.

To accurately determine the current HA and DEC position, modern incremental encoders (such as the US Digital HD-25 Industrial Rugged Sealed Optical Encoder, 2 channels in quadrature, 400 pulses per revolution) will be installed adjacent to the existing SLO-SYN synchro motor encoders, for improved reliability, PC compatibility, and tracking performance. The new encoders will be pinion-coupled and driven by the HA and DEC racks in the same manner as the original encoders. The encoders interface to the PC by means of an incremental encoder PCI card.

The Motion Control server controls the speed of the HA and DEC drives by means of electronic variable speed motor controls (Hitachi L300P Variable Frequency Inverters, or similar) through an RS485 PCI interface card. These speed controllers in turn connect to the 3-phase 208V motors, which are rated for inverter drive duty (WEG Totally Enclosed Fan Cooled [TEFC] Inverter Duty Series or similar).

To provide multiple back-up systems so that the antenna cannot be driven beyond its HA and DEC limits, the existing boundary mercury switches will be sensed as a motion cutoff backup. In addition, the existing mechanical microswitch limit switches will be hardwired to directly interrupt motor power in the event the dish should move to these limits.

The Stanford Space Systems Development Laboratory (SSDL) can control and monitor real-time tracking operations by means of a remote PC using a secure SSH connection to the Satellite Tracking Control Server via the Internet.

Satellite Tracking Upgrade Material Cost Estimate

Quan.	**Description**	**Ea.**	**Total**
1	Tracking Control Intel PC Server (being donated)	$ 0.	$ 0.
1	RS-485 Dual Port PCI Card	99.	99.
1	Hitachi 20 HP Variable Frequency Inverter	1,225.	1,225.
1	Hitachi 15 HP Variable Frequency Inverter	940.	940.
1	WEG 15HP 3600 RPM 208V 3-Ph. Inverter Duty Motor	580.	580.
1	WEG 20 HP 3600 RPM 208V 3-Ph. Inverter Duty Motor	665.	665.
2	US Digital HD-25 Industrial Sealed Optical Encoder	280.	560.
1	Incremental Encoder PCI Interface Card, US Dig PCI-4E	350.	350.
1	Analog & Digital Data Acquisition PCI Card	650.	650.
	TOTAL (less tax and shipping): [Note 2]		$ 5,069

Note 1: Gearing change cost for DBW900 reducer TBD.

Note 2: An initial $20,000 gift has been made to STAR Lab by supporters of the Friends of the Bracewell Observatory Association which is intended to be applied to the initial restoration of the 1st dish, and its associated satellite tracking upgrades for SSDL missions, building restoration and utilities.

Appendix C

STAR Lab
Antenna Refurbishment and Site Maintenance Agreement

ANTENNA REFURBISHMENT AND SITE MAINTENANCE AGREEMENT

This agreement is made as of ________________, 2005 by and between Stanford's Space, Telecommunications and Radioscience Laboratory (STAR Lab), a research group within the Department of Electrical Engineering of Stanford University, with offices at 350 Serra Mall, David Packard #355, Stanford University, Stanford CA 94305, and the Friends of the Bracewell Observatory Association (FBOA), a non-profit 501(c)(3) Delaware corporation with offices at 567 Canyon Road, Redwood City, CA 94062.

1. Purpose. STAR Lab wishes to refurbish, upgrade, and maintain the existing 60 foot antennas and associated facilities at Stanford's Field Site 515 with the goal of providing a high-bandwidth ground station facility in support of Stanford's Space Systems Development Laboratory microsatellite program. FBOA, a non-profit 501(c)(3) organization, dedicated to the refurbishment and maintenance of Site 515 for the benefit of Stanford University's faculty and students, as well as Stanford's community outreach efforts, shares this goal, and wishes to provide the labor, materials, and operating funds necessary for the above purposes on a long-term basis.

2. Definitions.

(a) Stanford Field Site 515 (Site 515) refers to the grounds at 3185 Alpine Road, and includes the antenna array and facilites constructed by Professor Ronald N. Bracewell, Director of the Stanford Radio Astronomy Institute (now STAR Lab).

3. Antenna Refurbishment and Site Maintenance Services.

STAR Lab will oversee and direct the refurbishment, upgrade, and maintenance activities at Site 515. To carry out these activities, FBOA will provide the following services to STAR Lab:

(a) Restoration, satellite tracking upgrades, and maintenance of the 60 foot antennas and associated facilities at Site 515.

(b) Maintenance of the grounds long-term to prevent dry brush overgrowth to meet fire safety requirements on an on-going basis.

(c) Support of the operation of the site for Stanford Satellite Ground Station use, and additional educational uses as described in this Agreement.

(d) Provide all necessary volunteer labor as well as the day-to-day supervision of the volunteer team activities.

(e) Provide all materials and operating funds necessary for the above purposes on a long-term basis in accordance with the term of this Agreement.

In return, the Friends of the Bracewell Observatory Association's volunteers and supporters will enjoy the satisfaction of promoting the advancement of research and education at Stanford. In addition, FBOA will enjoy providing the following services in support of Stanford's community outreach goals:

(f) The preservation and presentation of the history, technical information, and scientific contributions made at this site for the benefit of Stanford and the community. FBOA volunteers will provide all needed assistance to Stanford's Archivist in reviewing, organizing, indexing, scanning, and archiving Site 515 historical documents, many of which are currently in storage in Packard Room 038.

(g) Providing experienced volunteer mentors in microwave communication, satellite tracking, and amateur radio astronomy for interested Stanford students, as well as students from local community colleges and high schools.

(h) Providing supervised access to the dishes (between Stanford microsatellite passes and missions) for special projects by Stanford University faculty and students, local community college and high school students, and local community organizations that promote the pursuit of science and engineering education.

(i) Providing supervised radio telescope viewing of celestial objects by Stanford faculty, students, and members of the local community by appointment.

An initial $20,000 gift has been made to STAR Lab by supporters of the Friends of the Bracewell Observatory Association which is intended to be applied to the initial restoration of the 1st dish, its associated satellite tracking upgrades for Stanford microsatellite missions, building restoration and utilities. FBOA agrees to continue to fund and sustain operations on an on-going basis thereafter during the term of this Agreement.

4. Indemnification and Liability Release.

(a) INDEMNIFICATION BY FBOA. FBOA hereby agrees to indemnify, defend and hold harmless Stanford University, including Stanford's STAR Lab, STAR Lab's successors and assigns, and Stanford's School of Engineering from and against all losses, liabilities, claims, demands, causes of action, damages, fines, fees, costs, including reasonable attorneys fees, whether or not covered by insurance, arising out of, resulting from or caused by FBOA, or its employees, members, volunteers, supervised participants, or agents under this Agreement.

(b) LIABILITY RELEASE. FBOA will obtain a signed liability release agreement from each of its officers, volunteers, and supervised participants prior to their participation in any activities at Stanford Field Site 515, and provide copies of each signed release to STAR Lab within thirty (30) days of signature. A sample of the liability release agreement (waiver) form is attached as "EXHIBIT A: Release and Waiver of Liability and Indemnity Agreement." This waiver is identical to the waivers that have already been approved by Stanford's School of Engineering for FBOA participants in activities at Site 515.

5. Insurance

INSURANCE BY FBOA. FBOA shall obtain and maintain during the Term, as a condition of the Agreement, comprehensive general liability insurance coverage in such form and issued by such insurance company or companies as shall be reasonably satisfactory to STAR Lab, with coverage for bodily injury, including death, in an amount not less than One Million Dollars ($1,000,000.00) per occurrence, and with coverage for damage to or loss or destruction of property, including loss of use thereof, in an amount not less than One Million Dollars ($1,000,000.00). FBOA shall provide STAR Lab with a certificate of such insurance naming STAR Lab, Stanford's School of Engineering, and Stanford University as additional named insured.

6. Term. The term of this agreement is 25 years, renewable by mutual agreement thereafter.

7. Termination. This Agreement may be terminated by STAR LAB prior to the expiration of the Term in the event FBOA fails to perform its obligations hereunder. If STAR LAB determines that FBOA has breached any of its obligations under this Agreement, STAR LAB shall give notice to FBOA in writing specifying the manner in which STAR LAB believes FBOA has failed to perform its obligations. FBOA shall thereafter have a period of thirty (30) days from receipt of the notice to cure the default. If STAR LAB, in its sole discretion, determines that FBOA has failed to cure the default within such thirty (30) day period, this Agreement shall be terminated. In the event FBOA cures the default to STAR LAB's satisfaction, this Agreement shall remain in full force and effect for the balance of the Term.

8. Modification. This Agreement may not be changed, modified, released, discharged, abandoned, or otherwise amended, in whole or in part, except by an instrument in writing, signed by STAR Lab and FBOA.

9. Notice. All notices pursuant to or under this Agreement must be in writing.

10. Entire Agreement. This Agreement sets forth the entire agreement, superseding any previous oral or written communications, representations, or understandings.

11. Severability. In the event that any paragraph or provision of this Agreement shall be held to be illegal or unenforceable, such paragraph or provision shall be severed from this Agreement and the entire Agreement shall not fail on account thereof, but shall otherwise remain in full force and effect.

12. Successors and Assigns. This agreement shall be binding upon and for the benefits of the undersigned parties, their successors and assigns

13. Governing Law. This Agreement shall be governed by the laws of the State of California.

14. Counterparts. This Agreement may be signed in multiple counterparts, each of which shall be deemed an original and all of which shall together constitute one agreement.

IN WITNESS WHEREOF, the parties hereto have executed this Agreement the day and year above written.

STAR LAB

By: ______________________________
Name: Professor Umran S. Inan
Title: Director
Date:_____________

FRIENDS OF THE BRACEWELL OBSERVATORY ASSOCIATION

By: ______________________________
Name: Robert E. Lash, M.D.
Title: President
Date:_____________

“EXHIBIT A”

Release and Waiver of Liability and Indemnity Agreement

I hereby acknowledge that I am voluntarily participating in the activities at Site 515 (3185 Alpine Road), hereinafter referred to as "Activities". I will be personally responsible for my own safety during these Activities and assume all risks and accept full and complete responsibility for any and all damages and personal injury of any kind, including death.

I am aware that the Activities are hazardous, involving risk of serious bodily injury, death, or property damage and I am voluntarily participating in these Activities with knowledge of the risks. I expressly assume the risk of these dangers including, but not limited to, slips, falls, objects or persons falling on persons, equipment failure, injury from pointed equipment, injury, improperly administered first aid, lightning strikes.

As lawful consideration for being permitted by the group engaging in these Activities or any of its officers, agents, servants, volunteers, leaders, activity participants, or employees, herein referred to as Releasees, to participate in these Activities and/or use their equipment, the undersigned does for him/herself, his/her heirs, executors, administrators, legal representatives, guardians, distributees, and assigns, collectively referred to as Releasors, hereby release, waive, discharge, and relinquish any action or causes of action for personal injury, property damage, or wrongful death which may hereafter arise from the Activities or any pursuit incidental thereto wherever or however said pursuit may occur and for any period said Activities and pursuits may continue.

The undersigned further agrees that under no circumstances will Releasors prosecute or present any claim against Releasees for any causes of action, for personal injury, property damage, or wrongful death, whether the same shall arise by the negligence or non-intentional conduct of any of said Releasees from the Activities or any pursuit incidental thereto.

The undersigned and the remaining Releasors hereby agree to indemnify, save and hold harmless the Releasees and each of them from any loss, liability, damage or cost (including attorney fees) which Releasees may incur as a result of injury, death, or property damage to the undersigned, or from suit from such personal injury, death, and/or property damage to the undersigned.

This Agreement is intended to be as broad as is permissible under the law of the State of California and this Agreement shall be interpreted under the laws of the State of California. If any portion of this Agreement is invalid and/or is declared to be invalid by a Court of Law, the balance of the Agreement shall continue in full force and effect.

The undersigned has read and voluntarily signs the release and waiver of liability and indemnity Agreement and further agrees that no oral representations, statements, or inducements apart from the foregoing written Agreement have been made. The undersigned acknowledges that he/she has read the foregoing paragraphs and is completely aware of the potential dangers incident to engaging in the Activities, and is fully aware of the legal consequences of signing the within instrument.

Printed Name: ______________________ Phone: ________________

Signature: __________________________ Date: _________________