The Discovery Channel Telescope:

An Investment in Astronomical Science at Boston University

Telescopes as Laboratories

- Astronomy is a “passive” science; the experiment is the universe itself, and the telescope is the observational “laboratory”

- When astronomers lack assured access to large, modern telescopes, this is precisely the same as chemists, physicists, or biologists lacking assured access to state-of-the art laboratories in their own fields

- Assured access to a telescope means the operation of a privately-owned telescope by a university and its partners (not the federal government)

- BU’s Astronomy department is the only Astronomy department in the USA that does not have assured access to at least one telescope with a diameter of 4 meters or greater

Specific Challenges to Astronomers who lack Assured Access to Large, Modern Optical Telescopes

- Substantial competitive disadvantages compared to those who have assured access through their university's investment in a private facility
- Extremely difficult to win successful funding for observational science in an increasingly harsh funding climate
- Federal support for national, open-access facilities has shrunk considerably over the past decade, and is continuing to shrink; one cannot count on being able to carry out observational science in the optical and near-infrared parts of the electromagnetic spectrum using national facilities
- Very difficult to recruit and retain the best young faculty members and the best graduate students

Obtaining Assured Access to Large, Modern Telescopes

- Universities and private observatories form partnerships/consortia to build and operate these facilities
- Represents a truly substantial commitment of financial resources (typically many millions of dollars)
- Basic costs to the partners usually include initial buy-in, as well annual operations costs
- Buy-in and operations costs cannot be recouped by grant funding; funding is usually obtained through a donor base
- Costs of new instrumentation for the telescope, the scientific observations, and the analysis of the data are federally-funded through grants to PIs
- This is a major capital investment in the “bricks & mortar” that are necessary to carry out basic astronomical research, without which it is extremely difficult to obtain federal funding to carry out the science

The Discovery Channel Telescope (DCT)

- A new 4.3 meter optical/near-infrared telescope being built by Lowell Observatory, located 40 miles southeast of Flagstaff, AZ
- Substantial funding has been provided by Discovery Communications, Inc. ($10M) and personally by Mr. John Hendricks, founder and CEO of Discovery ($6M)
- Mr. Hendricks has been a member of Lowell Observatory's Advisory Board for 20 years, and it was his idea to build this particular telescope to insure the future of the Observatory as a first-class private research institute for the next 20 to 30 years
- Total cost to build the telescope is approximately $40M; no additional funding will come from Discovery and Lowell Observatory must find new donors and university partners
- Completion of the telescope is on schedule, with commissioning to take place in Spring 2011
- Very early science operations are expected in late 2012, with a gradual ramp-up to full and stable operations in 2013-2014
- Because of our long and fruitful existing partnership, Lowell Observatory is keen to have BU as the primary university partner in the DCT
- We are particularly interested in the DCT because it is an excellent match to the science goals of many of our astronomers, it would allow us to capitalize on an already strong partnership, and it presents a unique platform for cross-college participation at BU

How the DCT will improve BU Astronomy

- Recent published rankings of departments include a substantial component of “perception” (i.e., how the Chairs of departments view the strengths of similar departments at other universities)
- BU’s lack of assured access to a large, modern optical/infrared telescope is perceived by the community as being very negative; How can we possibly do the best science if we lack the basic tools that all of our competitors have?
- The DCT will result in a much stronger scientific “brand” for BU astronomy, and greater scientific reach throughout the discipline
- BU Astronomers will be able to better rise to meet the challenges of Astro2010, the new Decadal Survey of Astronomy, and be able to pursue truly world-class science
- The DCT will allow BU to win state-of-the art instrumentation and science projects
- The DCT, with BU instruments and observers, will become the “go-to” package for local Boston media outlets and, in the long run, will likely result in a national presence through the direct connection with Discovery Communications (which intends to highlight research with the DCT on its science channels)
- In addition to strong science, the DCT will provide strong, positive relations for BU with the general public since astronomy is one of the most easily accessible of the physical sciences

DCT Instrumentation

- DCT will support imaging and spectroscopy in the optical and near-infrared using one existing instrument and several new instruments

- The typical timescale for construction of a new instrument, through commissioning, to early operations, to “prime/stable” science operations is 3 years

- **DeVeny Spectrograph:** existing Lowell instrument for optical spectroscopy, will be refurbished and will likely be the only available instrument on the DCT until late 2013 or early 2014

- **Large Monolithic Imager (LMI):** new instrument for imaging being built by Lowell Observatory, fully-funded, construction has just begun

- **Near Infrared High Throughput Spectrograph (NIHTS):** new instrument for near-infrared spectroscopy being built by Lowell Observatory, fully-funded, construction has just begun

- **Flexi:** new instrument proposed by BU (PI: Dan Clemens) that will allow simultaneous spectroscopy of 84 objects via an optical fiber head that can feed any spectrograph, proposal is currently pending at NSF

- LMI and NIHTS should be available for use in late 2013 or early 2014 as science operations begin to ramp up; if funded in the current grant cycle, Flexi should be available for use in late 2014

Two Modes of Astronomical Science with the DCT

- BU astronomers will support two modes of science with the DCT
- Standard **"PI science"** where specific projects are lead by individual investigators, funded by individual grants
- **"Survey science"** where we will pool our resources to carry out a crucial, complementary survey to the all-sky survey that will be carried out by the Large Synoptic Survey Telescope (LSST); this will be funded by grants to multiple BU investigators
- Our scientific interests are truly diverse, but we have two common strengths: the completion of large astronomical surveys, and the long-term monitoring of time-variable objects. Both of these require extended, dedicated telescope access (over many years) for successful completion.

Astronomical Science Priorities: Astro2010

- Every 10 years, the US astronomical community makes a critical examination of the field and produces a "decadal survey" to inform funding agencies of the priorities for astronomical research over the next 10 years; Astro2010 is the most recent of these surveys

- Astro2010 lists numerous top priorities for astronomical investigation which are already the cores of existing science programs for BU astronomers, and which will be better addressed by use of the DCT (connections between dark and luminous matter; formation of stars, black holes, and planetary systems; the workings of black holes and their influence on their surroundings; the effects of rotation and magnetic fields on stars; the deaths of massive stars)

- Astro2010 states that the #1 priority for Large-Scale Ground Based Initiatives is the Large Synoptic Survey Telescope (LSST), a wide-field optical telescope that will relentlessly image the sky with a cadence of 3 days; with the DCT, BU astronomers will complete a unique, powerful survey in concert with LSST in order to capitalize on the data being produced by LSST

- Astro2010 lists as a "key discovery area" the field of Time Domain Astronomy; BU's planned survey with the DCT in concert with LSST will be exactly this: time-domain spectroscopy in the optical and near-infrared parts of the electromagnetic spectrum

- Astro2010 also makes it clear that Astronomy must serve the nation: "In a time of concern over waning interest in science and engineering, astronomical research plays an important role in capturing the public's attention and promoting science literacy." With the DCT, BU astronomers, BU science educators, and BU science journalists will work together to actively promote science literary in new and expansive ways.

Current Senior Personnel likely to use the DCT and their Near-Term DCT Science Programs

- Professor Elizabeth Blanton (discovery of very distant galaxy clusters and studies of the evolution and dynamics of galaxy groups; instruments: LMI and Flexi)

- Professor Tereasa Brainerd (dynamics of satellite galaxies, gravitational lensing by galaxy clusters, and studies of the evolution and dynamics of galaxy groups; instruments: DeVeny spectrograph, LMI, Flexi)

- Professor Dan Clemens (mapping the 3-d magnetic field of the Milky Way; instrument: Flexi)

- Professor James Jackson (imaging shock features due to outflows from the formation of low-mass stars; instrument: LMI)

- Professor Alan Marscher and Senior Research Scientist Dr. Svetlana Jorstad (time-variations of spectral lines and continuum emission from material nearby the supermassive black holes at the centers of quasars; instrument: Flexi)

- Professor Merav Opher (studies of the physics of “holes” in the interstellar medium of dwarf galaxies, and their connection to supernovae; instruments: LMI, Flexi)

- Professor Andrew West (low-mass binary stars as tests of stellar, chemical and dynamical evolution; instruments: DeVeny spectrograph, Flexi)

BU Science with the DCT in the First 3 Years (2013-2015)

Substantially complete by end of 2015:

• spectroscopy of binary star systems to test stellar, chemical and dynamical evolution (West)

• spectroscopy of satellites of large “host” galaxies to use dynamics to study the dark matter halos of the hosts (Brainerd)

In progress by 2014, complete after 2015:

• identification of distant galaxy clusters to constrain cosmology (Blanton)

• evolution and dynamics of galaxy groups (Blanton & Brainerd)

• cosmic magnification due to gravitational lensing by galaxy clusters (Brainerd)

• distance measures to 500,000 stars to probe the 3-d magnetic field of the Milky Way (Clemens)

• imaging of shock features associated with low-mass star formation (Jackson)

• time-variation of emission from material nearby supermassive black holes (Marscher & Jorstad)

• physics of holes in the interstellar medium of dwarf galaxies (Opher)

Forecasts: PI Programs

- Most funding for DCT will come from the NSF; the cycle is such that proposals are submitted in mid-November of each year and, if successful, are funded in the summer of the following year

- Having assured access to the DCT will make for enormous leverage with NSF review panels; all of our science programs are high-quality, eminently “fundable”, and with assured access to the DCT, the review panels will understand that this means there is no doubt that we will be able to obtain sufficient telescope time to carry out our investigations

- Professors Brainerd and West will be able to use the DCT in the period of very early science operations because their work can be done initially with the DeVeny spectrograph; they will both submit proposals to the NSF in fall 2011 that would support observations beginning in late 2012 and early 2013

- Because of the necessary development time for new instrumentation, the other PI science programs are best proposed to NSF starting in fall 2012, in support of observations beginning in late 2013 or early 2014

- Grants to individual investigators for specific science programs are typically 3 years in duration, funded at a level of $125k to $150k per year

- Once the DCT is in prime/stable operations mode (2014 and beyond) we anticipate of order $1M per year in NSF funding in support of PI science programs

Survey Science: Direct Complement to LSST

- LSST is a new 8-meter optical/infrared telescope, currently under construction in Chile, that will relentlessly survey the entire sky, revisiting each object every 3 days

- LSST is expected to identify numerous new, time-variable sources, including classes of objects that astronomers may never have seen before

- LSST is only an imaging telescope, it has no ability to carry out spectroscopic follow-up of the objects that it finds

- Spectroscopy provides vital information on chemical composition, temperature, energy generation mechanisms, magnetic fields, and line-of-sight velocities

- All of the LSST data will eventually be available to the public; however Professor West is an official collaborator with LSST and will have early access to the data

- As a direct complement to LSST, BU astronomers will use Flexi to carry out a comprehensive survey that focuses on deep optical and near-infrared spectra of the LSST objects that can be observed from Northern Arizona (approximately 30% overlap with LSST)

- Our survey with the DCT will provide enormous added value to the LSST survey and, in particular, will contribute substantially to pure “discovery science” through time-domain spectroscopy

- Although other observatories have some capability to carry out multi-object spectroscopy, none can match Flexi’s truly unique design and efficiency of data acquisition; therefore it is highly unlikely that any other comprehensive spectroscopic survey of the LSST sources will be carried out by any other collaboration

Forecasts: Instrumentation & Survey Science

- The combination of Flexi and the DCT will result in a unique capability to carry out highly-efficient multi-object spectroscopy
- Our proposed near-infrared spectroscopic survey of LSST objects, particularly time-domain spectroscopy of variable objects, is something that cannot be carried out efficiently by any other observatory, and yet it is a truly powerful complement to the LSST survey
- Given the prominence of LSST and time-domain astronomy in Astro2010, the funding of Flexi and our proposed survey are as close to a “sure bet” for funding as there can possibly be
- Construction of Flexi will generate $2M in federal funding, and Flexi should be operational in 2014
- The survey of LSST objects will begin with LSST survey operations (expected in 2018), and we anticipate it to generate **$N?** in federal funding

Future Senior Personnel Likely to Use the DCT

- Ours is a top-heavy department, with many very senior faculty members
- Three Astronomy faculty members are currently past the age of 65 (ages 66 to 71); none of these expects to be a DCT user
- Within the next 7 years, an additional five Astronomy faculty members will pass the age of 65
- Of the likely retirees in the next 7 to 10 years, only one (Prof. Marscher) expects to be a DCT user
- With retirements comes the opportunity to recruit the best young observers and to develop lines of research that we currently lack (most notably the exciting and fundamental field of extrasolar planets)
- We expect that, as retirements occur and new young faculty are hired, the faculty usage of the DCT for core science will increase
- Given the time frame for the completion of the DCT instrumentation (3+ years from now), replacement hires to fill the lines of retiring faculty with new DCT users is essentially ideal; having assured access to the DCT will enable us to recruit the very best young observers to our faculty!

Fostering Cross-College Collaborations with the DCT

Astronomy is one of the most popular sciences with the general public, and is an ideal platform for increasing science literacy. We have been working with our colleagues in SED and COM to develop concrete plans for interdisciplinary work that centers on astronomy. In addition, the development of new astronomical instrumentation has natural ties to ENG.

SED Collaboration (Professor Don DeRosa):

• Expand and deepen Lowell Observatory's successful outreach program to Navajo and Hopi school children in AZ, including a more modern "integrative" approach to all of the sciences

• Bring a version of the above program to the Boston area, initially as a summer program at BU that will include both science and social studies components ("How other cultures see the sky")

• In the long term, have a local classroom presence and pair Navajo and Hopi schools with local "sister schools" (the Haitian magnate school in Cambridge is a possibility)

COM Collaboration (Professors Doug Starr and Ellen Shell):

• With the theme of "The Telescope as a Tool for Social Change", COM students will produce documentaries of our above education/public outreach work

• COM students will produce videos and audio (radio) content highlighting science being done with the DCT, as well as educational videos for Lowell Observatory's renovated Visitor Center

ENG Collaboration:

• Professor Siddharth Ramachandran (ECE) is a co-Investigator on Flexi (PI: Dan Clemens)

How Much will the DCT cost BU?

- Cost scales directly with the amount of time on the telescope that is desired
- Dr. Jeffrey Hall (Director of Lowell Observatory) has provided a written estimate of the costs under various models
- Buying of single nights of time is extremely undesirable; this does not foster a true partnership, nor does it give the ability to carry out long-term projects that require extended commitment of time over the course of many years
- Given the number of BU astronomers who are likely to use the DCT and the magnitude of their science goals, the ideal arrangement would include at least 2 months of time on the DCT and some continuing access to the Perkins Telescope (necessary for the polarization studies that the Blazar Group is interested in carrying out)
- Total cost to BU for the “ideal” arrangement is in the $10M - $12M range
- Lowell Observatory has mortgaged its endowment in order to pay for the completion of the telescope and, so, would appreciate as much “cash up front” as possible
- If BU were to enter into a long-term agreement with Lowell Observatory, payments could be stretched out over as long as a decade

BU-Lowell Observatory Partnership (1998-2010): A Success Story

- BU is a partner with Lowell Observatory in the operation of the 1.8m Perkins Telescope
- BU astronomers designed and built the two primary science instruments in use on the Perkins
- This partnership has allowed us to carry out large, long-term projects that would be impossible to carry out on national facilities simply because there is insufficient time available on those facilities
- Our assured access to the Perkins has placed BU's Blazar Group at the forefront of research into the gamma-ray jets of quasars and other active galaxies. No other blazar research group in the world can carry out studies that match the shear magnitude of the studies being done by BU because they do not have sufficient long-term access to telescopes that can provide polarization measurements.
- Our assured access to the Perkins has allowed BU to carry out a unique, comprehensive survey of the Milky Way's magnetic field ("GPIPS"). GPIPS represents an increase of 100,000 in Galactic magnetic field information over previous studies. No other group in the world can compete effectively with GPIPS because of the combination of instrumentation and telescope access that we enjoy.
- While the Perkins has been very useful to a number of BU astronomers, it is a very small, outdated telescope
- BU and Lowell astronomers have grown to know each other well during our partnership, and all are eager to extend our very successful partnership to the next level by committing to the DCT