B. Narrative summary

This proposal was principally to design and deploy a new instrument for the Magdalena Ridge Observatory (MRO) 2.4m telescope at New Mexico Tech. The observatory presently has only one other instrument, an optical CCD with wide-band filters, and therefore is underutilized within the state of NM and at NM Tech for science not associated with observations of asteroids. The proposal required a great deal of institutional buy-in for the NESSI instrument, including both the matching components required by the NASA EPSCoR program, and an additional $1M worth of hardware, pledged from the NM Tech Vice-President for Research and Economic Development, Van Romero, to actually build NESSI. The reason the hardware funds were not included in the matching was related to the funds being derived from Federal sources.

The science intrigue and interest associated with NESSI, the New Mexico Exoplanet Spectroscopic Survey Instrument, is quite simply undeniable. The ability to derive the emission or transmission spectrum of an exoplanet transiting its parent star, often 1000 to 1 million times as bright, is astounding. Yet to date Hubble Space Telescope, Spitzer Space Telescope and several ground-based observatories have been able to accomplish just this feat. The strength of the technique rests more in the data collection and reduction process than in the size of the telescope aperture. This very fact enables smaller, ground-based observatories, where observing time is generally easier to obtain, as potential players in the exoplanet characterization science discussions and discovery. It was for this reason that the science case for NESSI was centered on exoplanets. Nevertheless, moderate resolution, near-infrared spectrometers are common work-horse instruments at all ground-based observatories today.

The development of NESSI started before the NASA EPSCoR funding began as a conceptual design. The proof of concept for the NESSI science case is derived from the Nature paper by Swain et al. (2010) using the SpeX instrument on NASA's IRTF. The key components in the NESSI design which the team believes sets it apart from other moderate-resolution spectrometers which might also be considered for exoplanet spectroscopic characterization include: a) Nasmyth port mounting to minimize changing gravity loads, b) use of multi-object cryogenic apertures instead of fixed/variable width slits to reduce coupling of varying seeing effects into the spectrometer throughput, c) thermal, vibrational and flexure stabilized instrument platform to reduce mechanical noise coupling into the system, d) a "staring" (as opposed to chopping/nodding) observing mode via the use of a multi-object spectrograph mode to ensure as many photons are collected during the observations as is physically possible, and e) high throughput and high dynamic range design so that fewer photons are lost, and those captured from the exoplanet in the presence of the bright parent star will not be lost in the inherent noise of the detectors.

The development of NESSI involved a distributed team at NM Tech, the Magdalena Ridge Observatory and NASA-JPL. At every stage in the design, best practices from NASA design teams were implemented in order to track instrument development and train the students and young engineers working on NESSI in professional observatory instrument development. These best practices included: a) development of

a requirements document, b) initial and final design reviews with external instrument scientists, c) tolerancing of all opto-mechanical components through software simulations within NESSI including development of alignment documents and procedures and Finite Element Analysis (FEA) modeling, d) weekly design team meetings and telecons with external vendors, e) development of requirements documents and obtaining quotes from external vendors for every piece of equipment purchased for NESSI, f) visits to external vendor facilities as warranted, g) complete professional drawing packages for all the mechanical components in NESSI, and h) an AIV (assembly, integration and verification) plan for deployment in the lab and at the MRO 2.4m telescope. Professional design reviews were held with JPL and external personnel (see below) at the initial and final design phases to insure that no major errors were made in the team's development of the instrument.

Many industries were involved in the building of NESSI as nearly all components for the instrument were externally purchased and then integrated and assembled in-house at NMT. All the optics for NESSI were custom designed by C. Jurgenson. Drawings for each optic, along with a series of quotes from vendors, were required for each of these custom optics and the coatings placed on them to minimize light losses. Graduate student, H. Bloemhard, worked with Jurgenson to tolerance the surfaces for the optics, to obtain all the quotes, and to track the vendor progress and deliveries. Filters and mirrors, which should typically be considered more "standardized" components required a similar level of effort because the required sizes, mounting tools and light-weighting of optics for NESSI to achieve the design requirements. The grisms (a prism with a grating affixed to its face) needed to be identified from among a library of available grism solutions already in existence, as there is only one vendor (Richardson Grating Labs) which produces this technology any longer at an affordable price for small projects. This work was supervised by postdoc K. Houairi. Mechanical design was overseen by two lead mechanical engineers at the MRO Interferometer, F. Santoro and A. Olivares. They worked with the NESSI team and with several students and young engineers at MRO to complete all the mechanical design of the NESSI structure (see Figure 1 in attached section). Components were manufactured at two professional machining plants in the Albuquerque area and using the NM Tech machine shop for small components and emergency issues. The cryogenic dewar, which houses the optics and detectors and operates at 80 Kelvin, was purchased from and built by Universal Cryogenics in Tucson, AZ. While many members of the team worked with this company, principal responsibility rested with our second postdoc, M. Hrynevych. The detectors for auto-guiding and infrared spectroscopic characterization, which are mounted in NESSI, are the best that money can purchase today and in total (for two detectors plus associated electronics) account for nearly half of the $1M of hardware spent on the NESSI instrument. Finally, NESSI requires a great deal of software to integrate the components and have them work together seamlessly. This work was started under the supervision of L. Schmidt and a team of about six undergraduate students over three years. Schmidt has subsequently graduated and stayed on to work with NESSI in a systems engineering capacity as a postdoc with the project/MRO. We consider the team integration and the tremendous success of all the student and engineering members of the organization the greatest success of the NESSI project.

Several collaborations are just beginning as part of the efforts of building NESSI. In 2012, P. Boston hosted a 3-day Exoplanet Workshop as a result of reaching the final design stages of NESSI. This

workshop included scientists from many fields who have an interest in the outcome of NESSI's science case (i.e. not just astronomers). These included atmospheric scientists, instrument designers, geologists, astrobiologists, planetary scientists and people who may one day be policy makers within NASA or their universities. We included students in this workshop so that they could benefit in seeing the process from the initial stages as well. More traditional collaborations are also beginning including exoplanet atmospheric scientists who undertake observing or modeling, scientists interested in the imaging modes of NESSI, and scientists interested in potential upgrade paths to NESSI.

There have been several nice press releases and local press pieces done to highlight the exciting science that NESSI promises to deliver (see below). Two in particular that are worth mentioning are a 5-minute news piece done by KRQE News out of Albuquerque for NESSI's first light commissioning run and a follow-on piece by NASA Headquarters/JPL. These two press releases can be found linked off on the MRO website: www.mro.nmt.edu. We anticipate many more press releases once commissioning is completed and NESSI is able to start taking exoplanet and other types of scientific data.

A final status report on the deployment of NESSI ends on a difficult note. After a 1-year delay due to a Federal funding slow-down, which required the NESSI project to request a no-cost extension to get into year 4 and purchase final components, we suffered another series of delays. The second series of delays are associated with the infrastructure and lack of personnel at the MRO 2.4m facility. Initial plans to place NESSI in the dome at the 2.4m in Nov, 2013 required lifting NESSI through the observing slit of the telescope because the elevators were found to be inadequate for the size of the instrument. While waiting to place NESSI on the Nasmyth of the telescope, it was found that a safety fault was tripped at the telescope when removing a piece of equipment not needed for NESSI operations. The telescope was initially inoperable and required a few weeks of investigation to find a work around. Another attempt at observing in Jan, 2014 was also thwarted due to a failure of the telescope mirror support structure, and thus NESSI first light was delayed until late March, 2014. In the first commissioning run, NESSI suffered some internal wheel errors and also software issues that had to be debugged in real time – all typical of commissioning. Nevertheless, NESSI acquired first-light within 12 hours of being on sky, despite these issues and weather closures due to 80+ mph winds. During the second commissioning run in June, 2014, it was discovered that a serious light vignetting issue exists for NESSI. This can be attributed to small misalignments of various optics either within or outside of the NESSI instrument. Subsequent testing of NESSI on its support cart has revealed the most likely cause for the vignetting is a misaligned beam from the telescope tertiary into the NESSI optics, and mitigation strategies have been developed and will be deployed later this year. However, the MRO 2.4m presently employs fewer than 4 full-time staff, including its director, and no dedicated observing assistants or telescope engineers. Assistance required to fix simple system failures is usually garnered via external contracts to engineers on a per visit cost basis. This operations model for the observatory is a root concern for the NESSI team at NMT and externally as we are concerned that long-term support of regular observing with NESSI may not be feasible at the MRO 2.4m.

Overall, we consider NESSI largely a great success and expect that once these initial commissioning issues are addressed, it will be a staple instrument for use of the ground-based exoplanet community and many types of other scientific investigations as well.

C. Supporting documents

1. Research

The proposed research objectives in the executive summary of the original NESSI proposal were the following:

1. Build a unique near-infrared spectrometer expressly suited for observations of exoplanet atmospheres.
2. Develop a stable hardware platform and data extraction and reduction pipeline for analyzing the data.
3. Deploy NESSI at the MRO 2.4m telescope to obtain dedicated observing time and start an exoplanet survey.
4. Employ students and postdocs in all parts of the design, assembly and testing of the system, and offer time for student observing in the 3rd year of the proposal to learn how to obtain and reduce exoplanet data.
5. Form a cross-disciplinary team of scientists within/outside NM to prepare for the interpretation phase of NESSI data and to participate in workshops in NM.

For each of the objectives above, we discuss our success specific to the intended outcome.

1. The NESSI team successfully designed, built and deployed the NESSI instrument at the MRO 2.4m telescope. This spectrometer is a multi-object (cryogenic mask), moderate resolution near-infrared spectrometer using the most sensitive infrared arrays available commercially today (Teledyne H2RG). It has built-in tracking and autoguiding capabilities using a red-sensitive CCD (from e2V), which will enable NESSI to characterize the reddest (M dwarf type) exoplanet host stars. Additionally, NESSI has very good imaging capabilities over a wide field-of-view (0.5" pixels over 12 arcminute field), which will permit other types of scientific investigations to be undertaken at NM Tech and for anyone able to pay for observing time on the MRO 2.4 meter telescope. While initial commissioning activities were delayed for more than one year for reasons associated with a delay in hardware funding and then a subsequent MRO 2.4m telescope failure, we were finally able to commission NESSI initially from March 29-April 5, 2014. A second commissioning run was undertaken June 1-4, 2014. A final commissioning run is yet to be scheduled. Therefore, except for completion of commissioning activities, the NESSI instrument has been completed and performs as designed in the laboratory setting. See the figure below for picture of NESSI on the 2.4m and a first-light image from NESSI.

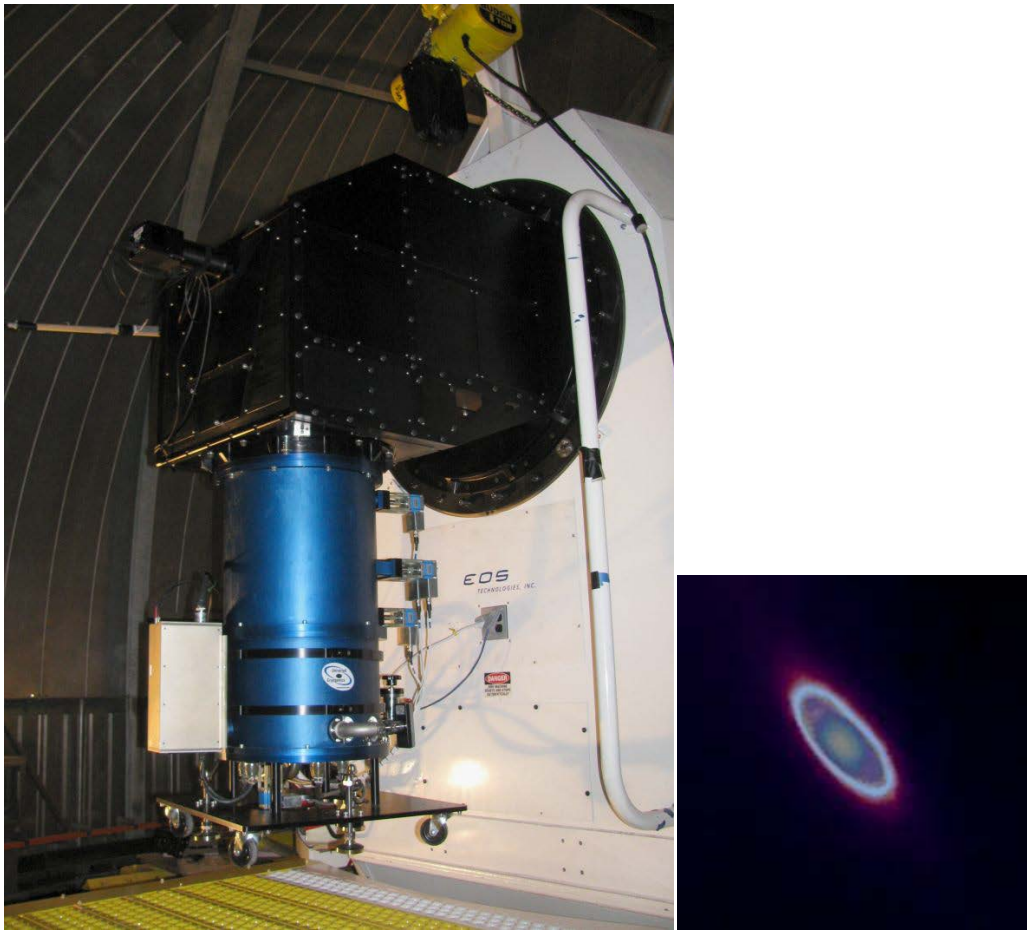

Figure 1: (left) NESSI on the MRO 2.4m scope during commissioning. (right) False-color subtracted (K-H band) image of Saturn using NESSI in imaging mode.

2. NESSI's design is inherently more stable than other spectrometers, in large part to the minimization of moving parts, a direct in-line optical design, and elimination of variable gravity loading for NESSI (e.g. through attachment to the Nasmyth port of the telescope instead of a Cassegrain port). The use of multi-object spectrograph masks within NESSI means the sky background coupling onto the array is inherently lower, improving the SNR of the instrument. Finally, parallel efforts at NMT by Ms. Bloemhard and at JPL by Dr. Swain and his Exospec Team, have developed data reduction pipelines which can be used to reduce and analyze NESSI exoplanet data. Therefore, once regular surveying of exoplanet targets commences (after commissioning is completed), data reduction pipelines exist for all NESSI spectroscopic observing modes.

Capability	Description	Wavelengths	Notes
Multi-obj. masks	12' FOV, 0.5" pixels	1.0-2.4 um	7 masks + open
Low-res. spectra	R~200	1.0-2.4 um (JH&K)	Teledyne H2RG detector
Mod-res. spectra	R~1100	1.0-2.4 um (J, H or K)	
Autoguiding	Optical/Red, 0.25" pixels	0.5-0.9 um, 4' FOV	E2V red CCD
Narrow-line imaging	Full-field imaging	13 filters selected	7 Filter slots
K-Mirror	Selectable angles	1.0-2.4 um	Spec'd for 0.3" tracking stability
Wide-band single object photometry	Magnitude limits TBD	J, H or K	

Figure 2: Table encapsulating NESSI's capabilities. There are a wide range of science applications for an instrument with NESSI's specifications.

3. Deployment of NESSI at the MRO 2.4m telescope took place in March-April and June, 2014. The results of commissioning have revealed what we believe is a mismatch between the telescope beam direction/angle and the NESSI instrument which resulted in vignetting of the science beam within NESSI. A mitigation plan is underway and we are waiting for confirmation of a final commissioning run later in 2014 to complete commissioning. Proposals have been submitted internally within JPL and to NASA to support survey work with NESSI once commissioning is completed.

4. We have employed more than half a dozen undergraduate students, two graduate students, three postdocs and several professional staff directly at the Magdalena Ridge Observatory Interferometer in the design, integration and assembly of NESSI and its associated software (see participants below). In this respect we believe that the NESSI project has been a tremendous success in training a new group of researchers in team-based instrument definition, design and deployment at a telescope. We were unfortunately unable to engage students at other institutions in the State in the potential use of NESSI for other types of science (not strictly exoplanet science, but also spectra of other objects or imaging) as commissioning was not completed during the project period. Funds for this part of the project are left unspent.

5. We have engaged external members of the astronomical community in the potential and promise of exoplanet spectroscopy that will become routine once NESSI and similar

instruments are in regular operation. We have also begun speaking with various groups within and outside of NM Tech about other types of science that might be undertaken with NESSI in imaging modes. This is in-part evidenced by the public talks given about NESSI (see below), and by the Exoplanet Workshop (May, 2012) held in NM which will hopefully result in a special issue article in the Astrobiology Journal. The astronomical community continues to be excited and engaged in the concept of exoplanet spectroscopy as a way to characterize these new worlds. A simple search of the terms "NESSI Exoplanets" in Google yields over 3000 results, suggesting we are starting to be noticed in the community.

2. Participants

Key Participants in NESSI design and implementation:

- Dr. Michelle Creech-Eakman, Associate Prof. of Physics, NESSI Science PI, New Mexico Tech, Socorro, NM
- Dr. Penelope Boston, Prof. of Geological Sciences, NT^2 Workshop Coordinator for NESSI Project, New Mexico Tech, Socorro, NM
- Dr. Mark Swain, Research Scientist, NESSI Science Collaborator, NASA Jet Propulsion Lab, Pasadena, CA
- Dr. Pieter Deroo, Research Scientist, Jet Propulsion Lab, Pasadena, CA
- Dr. Gautam Vasisht, Research Scientist, Jet Propulsion Lab, Pasadena, CA
- Dr. Luke Schmidt, Postdoc, Magdalena Ridge Observatory Interferometer, New Mexico Tech, Socorro, NM
- Dr. Colby Jurgenson, Research Scientist, Yale Univ., New Haven, CT (former Lead Optical Designer, Magdalena Ridge Observatory Interferometer, New Mexico Tech, Socorro, NM)
- Dr. Fernando Santoro, former Lead Mechanical Engineer, Magdalena Ridge Observatory Interferometer, New Mexico Tech, Socorro, NM
- Ms. Heather Bloemhard, PhD Candidate, New Mexico Tech, Socorro, NM
- Mr. Andres Olivares, Lead Mechanical Engineer, Magdalena Ridge Observatory Interferometer, New Mexico Tech, Socorro, NM
- Mr. Chris Salcido, Mechanical Engineer, Magdalena Ridge Observatory Interferometer, New Mexico Tech, Socorro, NM
- Mr. Matt Napolitano, student, New Mexico Tech, Socorro, NM
- Mr. Tyler Cecil, student, New Mexico Tech, Socorro, NM
- Mr. Jesse Crawford, student, New Mexico Tech, Socorro, NM

Associated Participants:

- Dr. David Westpfahl, Prof. of Physics, NESSI Outreach Coordinator, New Mexico Tech, Socorro, NM
- Dr. Van Romero, Vice-President for Research and Economic Development and MRO PI, New Mexico Tech, Socorro, NM

- Mr. Richard Cervantes, Assoc. Vice-President for Research and Economic Development and MRO Co-PI, New Mexico Tech, Socorro, NM
- Dr. Kamel Hourairi, former Postdoc, NESSI Team, Magdalena Ridge Observatory, New Mexico Tech, Socorro, NM
- Dr. Michael Hrynevych, former Postdoc, NESSI Team, Magdalena Ridge Observatory, New Mexico Tech, Socorro, NM
- Mr. Rob Selina, Science Manager, NRAO EVLA, (former Manager and Electrical Engineer, Magdalena Ridge Observatory Interferometer), Socorro, NM
- Dr. Pin Chen, collaborator and research scientist, Jet Propulsion Lab, Pasadena, CA
- Mr. Michael Chavez, machinist, Research and Economic Development office, New Mexico Tech, Socorro, NM
- Ms. Lisa Majkowski-Taylor, former Grants Manager for NESSI Project, New Mexico Tech, Socorro, NM
- Ms. Emma Aafloy, former Grants Manager for NESSI Project, New Mexico Tech, Socorro, NM
- Mr. Dan Rodeheffer, student, New Mexico Tech, Socorro, NM
- Mr. John Russell, student, New Mexico Tech, Socorro, NM
- Ms. Genevieve Vaive, student, New Mexico Tech, Socorro, NM
- Mr. Charlie Moore, student, New Mexico Tech, Socorro, NM
- Mr. Rob Kelly, student, New Mexico Tech, Socorro, NM
- Mr. Stephen Jimenez, Mechanical Engineer, Magdalena Ridge Observatory Interferometer, New Mexico Tech, Socorro, NM
- Mr. Mike Stanley, telescope scheduler and engineer, Magdalena Ridge Observatory 2.4m telescope, New Mexico Tech, Socorro, NM
- Dr. Eileen Ryan, Magdalena Ridge Observatory 2.4m telescope Director, New Mexico Tech, Socorro, NM

3. Systemic Change

Improvements in jurisdiction research and development infrastructure as a result of the NESSI project include: a) a more complete and well-developed instrument laboratory at NM Tech that is part of the MRO and is housed in Workman Center, b) a team of undergraduate and graduate students who worked with professional observatory staff, engineers and external technical vendors to specify and develop components for NESSI, c) a more mature operations model for the MRO 2.4m telescope including the ability to change out instrumentation to accommodate NESSI runs, d) development of a multi-object spectrometer and wide-field imager which will have applications for many fields in astrophysics.

Increased financial commitment from the jurisdiction, industry and participating institutions as part of the NESSI project include: a) engineering expertise and assistance by several of the MRO

Interferometer staff, and thus their time and salaries paid for by the project, b) industry participation to develop NESSI components in collaboration with the NESSI PI and team resulting in a mature instrument, c) assistance to assemble and deploy NESSI from several groups including vendors and investigators at JPL and Caltech who helped specifically with optimizing the readout of the detectors, d) interest from several institutions to use NESSI at the MRO 2.4m including faculty at NM Tech, researchers at JPL, NRAO, Yale and University of Massachusetts – Lowell.

The activities of deploying and observing with NESSI become ever more relevant as more transiting exoplanets are discovered. Excitement for the type of data that can be produced by NESSI was highlighted during a special session at the American Astronomical Society meeting in June, 2012 in Anchorage, Alaska. Dr. Creech-Eakman was invited to be the moderator for a special session, hosted by Boeing, concentrating on the future of exoplanet characterization programs and missions. Further evidence of NESSI's relevance in today's astronomical research community is the development of a funding call which cuts across both astronomical and planetary science areas (traditionally funded by separate divisions within NASA) to fund exoplanet research as a joint endeavor for both discipline areas.

There have not been any reordered institutional priorities within New Mexico Tech as a result of the development of NESSI as commissioning has not been completed and therefore regular observing with NESSI has yet to come to fruition.

4. Collaborations

NASA Centers:

- Initial Design Review: Instrument Requirements and Optical Design, at NASA JPL, Pasadena, CA, March, 2010. Reviewers: Mark Colavita, JPL; Nick Konidaris, Caltech; Mark Swain, JPL; Gautam Vasisht, JPL. Presentation team: M. Creech-Eakman, C. Jurgenson, K. Houairi.
- Final Design Review: Complete Design, at MRO, Socorro, NM, July, 2011. Reviewers: Mark Swain, Pieter Deroo, Gautam Vasisht all from JPL; David Buscher, Cambridge, UK. Presentation team: M. Creech-Eakman, C. Jurgenson, M. Hrynevych, F. Santoro, L. Schmidt, H. Bloemhard, G. Vaive, M. Napolitano.
- Briefing to Mike Werner and Wes Traub, NASA JPL/Caltech regarding status and plans for NESSI at MRO 2.4m, Jan, 2012.
- NASA JPL participants in Exoplanet Workshop, May, 2012 – Linda Brown, Gautam Vasisht, Pieter Deroo
- NASA Goddard participant in Exoplanet Workshop, May, 2012 – Shawn Domagal-Goldman
- NASA Goddard (and John's Hopkins Applied Physics Lab) briefings (by phone) to Carey Lisse, Ron Vervak and colleagues on possibility of using NESSI to do observations of Comet ISON, March--Nov, 2013.

Other Federal Agencies:

None.

Jurisdiction Agency:

None.

Other Academic Institutions:

- University College London, UK, Exoplanet Workshop, May, 2012 – Karl Mitchell (at JPL at the time), James Cho
- College of William and Mary, VA, Exoplanet Workshop, May, 2012 – Joel Levine
- University of Pennsylvania, Exoplanet Workshop, May, 2012 – Lisa Messeri
- University of Florida, Exoplanet Workshop, May, 2012 – Steve Benner
- Lowell Observatory, Exoplanet Workshop, May, 2012 – Travis Barman
- New Mexico Tech, Physics Department, ongoing discussions with Raul Morales-Jubieras, Rick Cosentino, Dave Meier, Lisa Young and other members of department in using NESSI for other types of imaging applications including observations of wave phenomena on Jupiter and wide-field, narrow-band imaging of galaxies, May, 2012 to present
- University of Arizona, Caitlin Griffith, companion proposals submitted to NASA, May, 2013
- Yale University, Deb Fischer and Nikku Madhusen, discussions about collaborating to use NESSI, Jan 2012-present.
- John's Hopkins Applied Physics Lab (and Goddard) briefings (by phone) to Carey Lisse, Ron Vervak and colleagues on possibility of using NESSI to do observations of Comet ISON, March--Nov, 2013.
- San Diego State University, Adam Burgasser, discussion in email about using NESSI to characterize brown dwarfs, Jan, 2014.
- Cambridge University, UK, Didier Queloz, discussion in email about using NESSI for exoplanet characterization, Jan, 2014.
- Univ. of Massachusetts, Lowell, Supriya Chakrabarti, discussions about upgrading NESSI's autoguiding capabilities to include an optical spectrometer, May, 2014.

Industry (Partners who participated in delivering components for NESSI):

- Machining done by: J.W. Industries in Albuquerque, NM and Pro-Fab in Bosque Farms, NM and the NMT machine shop
- Cryostat from: Universal Cryogenics in Tucson, AZ
- Components from: Newport Opto-mechanical Subdivision, NY; Optimation, UT.
- Optics from: Optical Surfaces Ltd, UK; Rocky Mountain Instruments, Denver, CO; Newport Richardson Gratings Labs, NY; Rainbow Research Optics, CO; ISP Optics, CA.
- Detectors from: e2V and Finger Lakes Instruments, NY and Teledyne Imaging, Los Angeles, CA.

- Electronics from: ARC Incorporated, San Diego, CA.

Others:

- NM Museum of Natural History, Albuquerque, NM, Exoplanet workshop, May, 2012 – Larry Pietro
- New Mexico Consortium – Discussions with Steve Buelow and Monica Wu regarding support of efforts at NMT with NESSI project, especially for Exoplanet workshop.
- See also list of talks for local groups interested in NESSI science.

5. Space Grant Interaction

In 2010, Dr. Creech-Eakman, Dr. Boston, Ms. Bloemhard and Dr. Deroo attended a New Mexico Space Grant Consortium presentation and gave an update on the status of the NESSI project at the invitation of Dr. Pat Hynes, held in Las Cruces, NM.

Ms. Heather Bloemhard submitted and was awarded a $10,000 Graduate Student Fellowship in 2012 to continue work she had started on the NESSI project, in particular characterizing exoplanet atmospheres using data taken at NASA-IRTF and writing software reduction code using these data that can be used for reducing NESSI data as well. Ms. Bloemhard also attended two exoplanet conferences using the funds from this fellowship and assisted summer students (summer 2014) working with Dr. Swain and his Exospec team on learning how to reduce data from some of NESSI's initial commissioning runs.

6. Success Stories

Peer reviewed and similar levels of publications or accreditations where NESSI is discussed include:

- Boston, P., Creech-Eakman, M. et al. (7 co-authors), "Exoplanets: Not Just Dots in the Sky Anymore", 2010, Astrobiology Science Conference, Evolution and Life: Surviving Catastrophes and Extremes on Earth and Beyond, April, 2010, League City, TX, No 1538, 5490.
- Jurgenson, C., Santoro, F., Creech-Eakman, M. et al. (10 co-authors), "NESSI: the New Mexico Tech Extrasolar Spectroscopic Survey Instrument", 2010, SPIE, Vol 7735, 19J.
- Creech-Eakman, M., Jurgenson, C., Santoro, F. et al. (12 co-authors), "NESSI: an optimized Near-Infrared (NIR) Multi-Object Spectrograph (MOS) for Exoplanet Studies", 2012, SPIE, Vol 8446, 7YC.
- Santoro, F., Olivares, A., Salcido, C., et al. (12 co-authors), " Mechanical design of NESSI: New Mexico Tech extrasolar spectroscopic survey instrument", 2012, SPIE, Vol 8446, 9GS.

Presentation at conferences, talks and presentations at meetings where NESSI is discussed/presented include:

- Creech-Eakman, M., Jurgenson, C. et al. (4 co-authors), “The New Mexico Tech Extrasolar Spectroscopic Survey Instrument”, Jan, 2010, American Astronomical Society, Talk, 21538704C.
- Houairi, K., Jurgenson, C. et al. (6 co-authors),” NESSI: the New Mexico Tech Extrasolar Spectroscopic Survey Instrument”, Jan, 2010, NRAO NM Symposium, Poster, 27H.
- Creech-Eakman, M., “NESSI, Exoplanet Atmospheres and IR Spectroscopy at NMT”, Earth and Environmental Sciences Department, Colloquium, Oct, 2010, New Mexico Tech.
- Creech-Eakman, M. “The Search for and Characterization of Extrasolar Planets”, Enchanted Skies Star Party, invited talk, October, 2010, Socorro, NM.
- Bloemhard, H., Creech-Eakman, M., Deroo, P. and Zhao, M., “IRTF/SpeX NIR Emission Spectra of WASP-1b”, Jan, 2011, American Astronomical Society Conference, Poster, 21812808B.
- Creech-Eakman, M. “The Search for and Characterization of Extrasolar Planets”, Socorro Rotary Club, invited talk, April, 2011 Socorro, NM.
- Hrynevych, M., Jurgenson, C., et al. (8 co-authors),”NESSI: the New Mexico Tech Extrasolar Spectroscopi Survey Instrument”, Nov, 2011, NRAO NM Symposium, Poster.
- Creech-Eakman, M., “NESSI, Exoplanet Atmospheres and IR Spectroscopy at NMT” Physics Department Colloquium, Nov, 2011, New Mexico Tech.
- Special Session Moderator: M. Creech-Eakman, “Characterization of Exoplanet Atmospheres”, Wed, June 13, 2012, American Astronomical Society, Anchorage, Alaska.
- Bloemhard, H., Creech-Eakman, M., Jurgenson, C. et al. (4 co-authors and Exospec Team), “Characterizing the Atmospheres of Highly-Irradiated Jupiters”, Jan, 2012, American Astronomical Society Conference, Poster, 21924515B.
- Creech-Eakman, M. “Alien Sunsets, Spotted Stars and NESSI in New Mexico”, NM Museum of Natural History, Centennial Lecture Series, August, 2012, Albuquerque, NM.
- Bloemhard, H. “NESSI: A New Way to Study Exoplanets”, October, 2012, Enchanted Skies Star Party, Socorro, NM.
- Bloemhard, H., “NESSI: Exploring Exoplanets at MRO”, October, 2013, Enchanted Skies Star Party, Socorro, NM.
- Bloemhard, H. Creech-Eakman, M., Swain, M., Deroo, P. and Line, M., “Day-side Spectrum of the hot-Jupiter WASP-1b”, Jan, 2014, American Astronomical Society, Poster, 22334722B.
- Deroo, P. “ExEP PPBE PY ’16 – NESSI: New Mexico Exoplanet Spectroscopic Survey Instrument”, JPL briefing, April, 2014, Pasadena, CA.
- Bloemhard, H., “Exoplanets in New Mexico”, Socorro Amateur Radio Association, August, 2014, Socorro, NM.

Awards associated with work on NESSI:

- Bloemhard, H., Chambliss Graduate Student Award for Poster Presentation, May 22-26, 2011, American Astronomical Society Meeting, Boston, MA, http://aas.org/grants-and-prizes/chambliss-astronomy-achievment-student-awards

7. Patent apps

No new technology was derived for which patent applications could be made.

8. Patent awards

No patents were awarded for this work.

9. Technology Transfer

A technology transfer for NESSI as an integrated instrument will be made once commissioning is completed and results can be verified.

10. New Non-EPSCoR Grants

Several NASA grants and one NSF grant have been applied for as a part of the NESSI project, to date none have been funded. We are presently waiting to hear about a NASA grant that was applied for in May, 2014 under the new Planetary Atmospheres concentration. A small grant of $10k was awarded by the New Mexico Consortium in May, 2012 to support the participation of investigators in the NT^2 summer workshop, "Making new Worlds: Atmospheric, Thermal and Astrobiological Interpretation of Exoplanets". The proceedings of this workshop are under development for a special issue in the journal Astrobiology. Additionally, JPL has awarded Dr. Mark Swain internal research and development funding, which he intends to use to purchase observing time with NESSI.

11. New Courses

An upper-level undergraduate/graduate course in Astrobiology is presently being offered for the 4^{th} time at New Mexico Tech, which is highly relevant to the NESSI science case. Dr.'s Creech-Eakman and Boston (and also Dr. Tom Kieft, NMT Biology Department) team teach the course. The course teaches the basics of the science of astrobiology using the Drake Equation as the framework for the course content. It includes an RFP opportunity for the graduate students to apply to in order to practice

grant-writing skills, and has an interdisciplinary capstone project of creating a planet/solar system with life-form(s) and a mission to detect the life-form(s) written as both a group narrative and a group presentation and defended scientifically for accuracy. As part of this course, we regularly bring outside speakers who are experts in various aspects of astrobiology to speak to the class participants and campus as a whole, some of whom have included: Dr. Seth Shostak, SETI Scientist; Dr. Peter Deroo, JPL, Exoplanet expert; Dr. Chris McKay, Univ. of AZ, Mars expert; and Dr. Lynn Margulis, UMass Amherst, Biologist and developer of Gaia Hypothesis.

Dr. Boston also regularly teaches a living-learning community course for incoming freshman (and occasionally also a Master's of Science Teachers course) called "Spaceship Earth" which teaches participants to see Earth in the larger context as a planetary body in the solar system, and likely one of a continuum of planetary bodies throughout the galaxy. The basis for this course was developed by Dr. Boston before coming to NM Tech, but has benefitted from her participation in the NESSI project.

Additional courses that have taken content from work associated with the NESSI project include Physics 334: Radiation and Optics, and MST courses in physics and astronomy and geology taught by the three main professors on the NESSI project at NMT.

12. PR Material

A list of recent highlights in the media on NESSI follows below:

1) KRQE news piece on NESSI: http://krqe.com/2014/04/04/nm-tech-exoplanet-search-is-earth-alone
2) JPL news piece on NESSI: http://www.jpl.nasa.gov/news/news.php?release=2014-117
3) NMT news piece: http://www.nmt.edu/nmt-news/336-2011/4414-new-instrument-will-join-study-of-exoplanets