# Goddard Space Flight Center

# IRAD Program

# FY04

## "Preparing Goddard for Large Scale Team Science in the 21st Century: Enabling an All Optical Goddard Network Cyberinfrastructure "


Abstract

The purpose of this proposal is to establish a "Lambda Network" (in this case using optical wavelength technology and 10Gbps Ethernet per wavelength) from GSFC's Earth science Greenbelt facility in MD to the Scripps Institute of Oceanography (SIO) through the University of California, San Diego (UCSD) facility over the National Lambda Rail (NLR), a new national dark optical fiber infrastructure. Currently, the Earth Science Directorate maintains a Joint Center with SIO where research collaborations exist between more than a half dozen scientists at each institution. This Lambda-Net will allow SIO scientists to interactively perform complex collaborative analysis with their Goddard colleagues across the continent as if they were in the same building, by making data residing on Goddard's high speed computer disks available to SIO with access speeds as if the data were on their own desktop servers or PC's. It will enable scientists at both institutions to share and use compute intensive community models, complex data base mining and multi-dimensional streaming visualization over this highly distributed, virtual working environment. It will create a virtual lab within Building 33 with a SIO wing.


## Principal Investigator & Co-Investigators


| | |
|---|---|
| Name: | Pat Gary & Jeff Smith Co-PI's,<br>& the ITPWG as Co-I's |
| Organizations: | Code 930, Code 420, Code 580, Code 920 |
| Telephone: | 301-286-9539 & 301-614-5038 for Co-PI's |
| E-mail: | Pat.Gary@nasa.gov, Jeff.Smith@nasa.gov |

# Technical Content

We propose as our first prototype study to connect the SIO as a virtual wing of Building 33 by establishing a "lambda net". This network will tie together two of the nation's leading Earth Science Centers to create a virtual powerhouse Laboratory of Earth scientists to address the challenges of understanding climate change and its national and global consequences for humans. Goddard has over the years developed close collaborations with leading institutions in the science community with many visitors to its labs and facilities. In particular, the Goddard Earth Sciences Directorate has established a Joint Center with SIO and has many complimentary collaborative investigations with SIO scientists. For example, Dr. Paul Houser and Mike Bosiliovitch of Code 970 are collaborating with Dr. John Roads of SIO on a Coordinated Earth Observing Program under GEWEX. Moreover, Dr. Roads also is Director of the Experimental Climate Prediction Center for California where, in collaboration with Dr. Max Suarez of Code 900.3, Mike Seablom of Code 560, and a UMBC graduate student working with Dr. Milton Halem, GSFC Emeritus, Dr. Roads plans to run interactive distributed regional model forecasts using boundary forcing conditions from the Global Modeling and Assimilation Office (GMAO) global climate model. Dr. Yoram Kaufman of Code 910 is collaborating with Dr. Ramanathan of SIO on an Aerosol project. Dr. J. Herman of Code 910 is the Co –I with Dr. Francisco Valero of SIO who is the PI on the Triana mission, and Dr. Michelle Rienecker of Code 900.3 is collaborating with Dr. Tim Barnett of SIO on the assimilation of global sea height data from Topex and Grace. In addition, Code 920 has collocated one of its geophysical scientists at SIO and Prof. Richard Sommerville has one of his modelers remotely providing computational science support to the NCCS of Code 930. These are but a few examples of why we expect this collaboration with SIO utilizing this L-Net technology will greatly facilitate the collaborations by making possible virtual data archives, grid cluster computing, and streaming visualizations across the continent seem as though all resources, both human and hardware, were all collocated in one adjacent Facility. As a result, this proposal will make Goddard more competitive with other west coast universities, agencies, and other NASA Centers by virtually eliminating the geographic barriers to such collaborations.

Networking technology has been doubling in bandwidth speeds approximately every nine months over the past decade, which is even faster than the exponential growth of Moore's law (~18 months for transistors on a chip), and is expected to continue this growth rate at least for the next decade. This exponential growth in bandwidth promises to revolutionize the way science will be done in the coming decade as much as the exponential growth in computing power has changed how scientific analysis is now done. Lambda-Nets (L-Nets) are the next generation of networking technology; they utilize dedicated dark optical fiber lines for multi-wavelength propagation of light employing optical switches to route the packets of light rather than converting them to electronic signals thus forming an all-optical network. This can result in unprecedented data transfer rates which with an 8-way optical crossbar switch can attain aggregate network throughput speeds greater than 80Gbs with >10Gb/s per wavelength.

The National Science Foundation (NSF) is currently funding the research into this the next generation cyberinformation architecture for data-intensive science research. One instantiation of that architecture is for integration of voluminous data stores, and high-attainment processing power through grid computing. NSF already has invested more than $15 million in this effort, with much of the funding directed to a university consortium ITR proposal called " OptIPuter" led by the UCSD. A second grant from the NSF to USCD consists of establishing a geodynamics community cyberinfrastructure called GEON. Much of the initial scientific work is focused on the geo sciences and Earth System Science research. Goddard has been invited by the PI's of both these projects to participate as members of the UCSD/SIO OptIPuter team as well as the GEON team because of its unique data holdings and modeling resources. A virtual Goddard presence with or on such L-Nets to UCSD/SIO will enable those collaborations to capitalize on the massive body of satellite data and extensive software and middleware to enable highly-prevalent data grid computing. Under this kind of scenario, for example, the Earth science directorate in Building 33

with four current wings of laboratories will appear as having a fifth virtual wing dedicated to SIO.

Goddard's solid earth research community has a number of data sets and models that are good candidates for use within the IT infrastructure proposed herein and are, in particular, well suited for developing collaborative research efforts with the University of Southern California and SIO. These include a new Comprehensive Magnetic Field model, crustal deformation models and data, lidar topographic and image data, gravity field models, core convection models, and earth rotation data and models. Recent discussions with the NSF-funded GEON team, whose PI Dogan Seber is also at the UCSD, have identified some of these models and data sets as possible Goddard contributions to that IT infrastructure development activity.

In future plans, after the NLR is extended to New York, we plan to connect GISS as a virtual wing in B-33. We already have been approached by the atmospheric Centers CEAS and CIRA at Colorado State University (CSU), who also wish to develop such a virtual collaborative presence with Goddard. Clearly, as this technology gets more mature, we can envisage many other such collaborations enabled by a Goddard L-Net not just for Earth science but also with collaborators of the Space Science Directorate. Eventually, one can see Building 33 having a dozen virtual wings each supporting a collaborating joint center, lab or Institute.

## *Technology Objectives – Products and Milestones*

This technology is still in a very early stage of industrial development and has not yet been tested under the data-intensive compute environment needed for certain Earth science applications. As early users of this technology, Goddard will gain expertise in the application of advanced lambda network technologies for the Earth and space sciences. Goddard has established many joint centers, and in particular with the SIO as well as CSU. It therefore is natural for Goddard to take the agency science lead in this area which we expect will be part of a new NASA cyberinfrastructure initiative. Goddard will become a member in the NLR in order to gain access to their network and on it construct a GSFC-SIO lambda path between McLean, Virginia and UCSD. NLR membership will provide rights by which Goddard can marginally add optical network components to create a GSFC-SIO lambda path on NLR's dedicated fiber optic lines with appropriate lambda relay switches that span the country. This membership is the most cost effective means today for Goddard to acquire a L-net to California. We will acquire a connection between Goddard and the drop at McLean through Goddard's existing membership in the Mid-Atlantic Crossroads (MAX) consortia to establish a working end-to-end lambda network to UCSD. The MAX maintains a DC metropolitan lambda core network now with points-of-presence (PoP's) in Arlington, DC/GWU, DC/Eckington, and University of Maryland College Park (UMCP); and is pursuing options for extending its connectivity to reach the NLR regional PoP in McLean. Goddard already leases fiber to UMCP and will lease an additional pair if needed for this L-Net. At the other end, SIO is committed to making the optical network connection from Scripps to UCSD thereby completing the last mile from Scripps to Goddard. We plan to test this connection performance using realistic data analysis and climate modeling experiments between GSFC/SIO science models in support of CEOP (an international coordinated Earth observation program that begins its intensive observation effort in 2004 to measure the global surface hydrology for a year). In addition, by collaborating with colleagues at University of Maryland Baltimore County (UMBC) and UMCP, we also plan to install and test an internal lambda net within Goddard using their optical switches to link various Goddard Beowulf type cluster computers across the center with the Goddard-wide Storage Area Network Pilot to enable not just Earth science modeling and analysis but also to support astrophysics and space physics modeling supporting LISA and SDO. The specific objectives consist of:

| *Statement of Objective* | *Initial TRL* | *Final TRL* |
|---|---|---|
| 1. Introducing elements of the NSF cyberinfrastructure and associated middleware to the research community at Goddard. | 4 | 6 |
| 2. Demonstrating how the lambda net and accompanying middleware can help to build "virtual communities" for science research. | 4 | 6 |
| 3. Developing and nurturing collaborations with the UCSD university consortium, particularly with SIO, one of the key consortium members, which will be the focus of the prototype. | 4 | 6 |
| 4. Extending the capabilities of the Earth System Modeling Framework (ESMF) such that interoperability between models, model components, geospatial services, and other functions can exist across distributed computing platforms. | 4 | 5 |
| 5. Understanding and resolving technical issues associated with the lambda network and demonstrate its capabilities to the Goddard community. | 4 | 6 |

## *Justification & Benefits – What future missions, opportunities will be enabled?*

There appears to be an administration thrust across the agencies by OSTP/OMB to reinvigorate the nations cyberinfrastructure. NFS has already established such a program and NIH has announced a roadmap initiative to redefine the ways medical research is conducted by building new pathways and networks for discovery. In recent days, NASA Headquarters (P. Cinager) has presented to the NASA Advisory Committee (NAS) a proposal that NASA enterprises develop a cyberinfrastructure program focused on NASA unique requirements. The NAS has requested a more detailed presentation and briefing in their next meeting in March. One outcome of this initial Goddard cyberinfrastructure effort will be to position Goddard to take the lead in the science application challenges if the agency moves forward with this initiative. Ames is looking to collaborate with Goddard as the principal Earth science partner in this effort much as it did in the past with the HPCC program. As a further benefit, this proposal will enable Goddard to develop real-time interactive collaborations with leading Earth and space science academic institutions thereby positioning Goddard to be more competitive in going after future science missions and research solicitations. In addition, the Engineering IDC lab will benefit from such an infrastructure by enabling interactive 3-D geometric design and planning simulations. Particular missions that will benefit from a cross continent Goddard L-Net are the NPOESS Preliminary Project (NPP) which is expected to develop near real time Climate Data Records, EOSDIS with its plan to evolve to its next generation system with distributed on-line national data access in Fairmont, W. Va. and elsewhere, LISA and its intensive modeling needs, the NOAA/NCEP-Goddard/GMAO Joint Data Assimilation Center with access to the NCEP's back up computer system also at Fairmont, W. Va., GPM, and other new potential missions like Blue Horizons.

## *Technical Approach*

National Networking Approach

We plan to construct part of the L-Net using the NLR. NLR participants pay for the right to operate their own L-nets. Each participant operates a user network over one or more optical waves or "lambdas" within the NLR national dark fiber infrastructure.

NLR management is a confederation of regional consortiums committed to deploying the national dark-fiber infrastructure. The Mid-Atlantic Terascale Partnership (MATP) is the mid-Atlantic regional consortium controlling who has use of the NLR from our region. This IT pathfinder project will establish access to the NLR through a MATP membership arrangement. Likewise, the Cooperation in Educational Networks in California (CENIC) is the San Diego NLR regional consortium. CENIC will provide access to the NLR for SIO.

This IT Pathfinder project will obtain rights to the NLR dark fiber fabric and operate a 10 gigabit per second (Gbps) lambda service over the NLR between the DC and San Diego regional NLR PoPs. The NLR rollout of dark fiber that could support a DC-San Diego user network should be completed by Spring 2004.

Regional Networking Approach

The NLR regional PoP in the DC metro area is located in McLean. The MAX maintains a DC metropolitan lambda core network now with PoP's in Arlington, DC/GWU, DC/Eckington, and UMCP; and is pursuing options for extending its connectivity to reach the NLR regional PoP in McLean. Goddard currently operates three dark fiber pairs between Goddard and the MAX PoP located at UMCP.

The MAX could carry an NLR lambda extension over the MAX Core by Summer 2004; but these plans are not yet firm, and potential implementation costs are only rough estimates at this time. We expect, however, that an adequate connection should be able to be established experimentally, especially given that the NSF also recently selected for award the MAX engineer-led "DRAGON" experimental network proposal for which Pat Gary provided a GSFC Letter of Support. Via DRAGON, a Movaz RayExpress optical network add/drop multiplexer will be set up at GSFC, connected to new all-optical switches from Movaz which will be placed at UMCP and University of Southern California's Information Science Institute-East in Arlington as the core of DRAGON's experimental multiwavelength optical network, and extended to other end sites such as George Mason University and the NCSA Access facility in Arlington.

In cooperation with the MAX, we plan to configure a 10 Gbps lambda that meets NLR frequency specifications between the Goddard campus and the MAX deployed over one new pair of dark fiber. The MAX will carry the lambda to the NLR PoP in McLean.

As a backup strategy not involving the MAX, we have obtained a quote from Level 3 Communications for an approach which would provide GSFC with use of new dark fiber directly between the NLR PoP in McLean and GSFC in Greenbelt. The cost for installation and use of this dark fiber together with GSFC acquiring, installing, and operating the needed optical network components to enable a L-Net compatible lambda between the NLR PoP in McLean and GSFC in Greenbelt is approximately the same as the approach proposed via the MAX (which has a more cost-effective potential in the future for "branching" the L-Net to other institutions in the mid-Atlantic region).

For either approach above, the NLR will support the lambda over their national fiber infrastructure to their PoP on the UCSD campus. SIO will provide their own lambda service between their campus and the NLR PoP at UCSD.

Campus Network Approach

We plan to extend the SIO-Goddard lambda service as close to the Beowulf clusters as practicable. The campus lambda service will interface with and expand on presently installed local area high end computer networks, will utilize existing campus dark fiber, and will leverage existing lambda networking resources to establish the L-Net.

The GSFC Science and Engineering Network (SEN) presently provides minimally 1 Gbps connections among Goddard high end computer network users and the Internet2's Abilene wide area research and education network. Built with Gigabit Ethernet (GE) switches/routers capable

of IEEE 802.3ad link aggregation and handling Ethernet jumbo frames, the GSFC SEN presently supports ~100 1-GE user connections with its current infrastructure of a 2-GE link with the MAX at UMCP using course wave division multiplexing over a single fiber pair between GSFC and the MAX at UMCP, 4-GE inter-building backbone links among GSFC buildings 28, 32, and 33, and 1-GE inter-building backbone links with GSFC buildings 22 (particularly including Code 586's Advanced Data Grid node) and 23.

We plan to interface the 10 Gbps L-Net initially with the GSFC SEN using one of the 10-GE ports of a recently acquired Force10 10-GE switch/router.

We plan to use concepts from Pat Gary's cyberinfrastructure-related DDF proposal and other related resources to provide both for host-to/from-network connectivity for the first GSFC cluster to be connected to the L-Net and for an inter-building "extension" of the L-Net from the initial building where the L-Net will connect with Goddard to a second building and a second cluster.

In future plans, after GSFC's initial cluster connections to the L-Net are demonstrated to be viable via this proposal, we plan to expand the local L-Net increasing the number of buildings/clusters connected to the L-Net.

"Seed" Application Approach

One of the most significant applications of L-Nets is its potential for integrating highly complex scientific models, data, computers, and related tools for collaborative research. For example, with such networking speeds, data residing on high-speed disks can be transported across the country to compute clusters as though those disks were in the same computer room as the processors. In a related initiative, NASA's Earth Science Enterprise has recently funded the Earth System Modeling Framework (ESMF), an effort involving the nations leading global climate modeling groups, to build a common infrastructure such that diverse scientific groups can leverage common software to build interoperable climate modeling components for a wide range of applications. Combining the ESMF software being developed as a Goddard led project with the Goddard L-Net enables an exciting potential for integrating adaptive agent technology for synthesis of Earth Science modeling information.

We plan to use concepts from Mike Seablom's ESMF-related DDF proposal as the seed application project for this grand collaboration between Goddard and SIO, in collaboration with the UCSD-led "OptIPuter" consortium, such that Goddard's Earth Science numerical algorithms and associated modeling tools and data objects would execute seamlessly with cyberinfrastructure middleware being built at UCSD. By working with the NSF funded "OptIPuter" consortium in such a manner, we envision Goddard models and data products would be more widely shared with and accessed by the SIO research community. We expect that the current growing industrial trend for data and computing grids, will only accelerate in the next few years with the arrival of ultra high bandwidth optical networks and the software tools like ESMF. Thus, an opportunity not previously practical is emerging for Goddard, to take a lead in large science teaming collaborations with other universities and research institutions, to utilize its massive satellite data holdings to increase future Goddard competitiveness in maintaining its unique leadership position in the application Earth System Satellite Climate Data Assimilation and Predictive Modeling

## *Schedule*

During the initial year for this proposed activity we plan to accomplish the following milestones:

1. Formalize a working relationship with key members of Code 900 for this pilot demonstration. Quantify requirements for the L-Net and acquire the system components and make the NLR partnership arrangements to support an end-to-end science scenario test**.** The scenario will make use of ESMF software tools and methods to enable rapid integration of the ensembles of climate data predictions on the fly across the country**.**
2. Establish requirements for a working network system internal to GSFC. Also establish a

design for prototyping the interfaces between components of the network system. The design should also accommodate a fully functional system.

3. Meet with key members of the SIO/UCSD and GMAO/ESMF teams to discuss technical issues. Address requirements for new methods and/or messages that would be desirable for supporting GSFC models and data assimilation. Also establish a working relationship with the network vendors and define requirements for utilization of the L-Net.
4. Execute the prototype L-Net, demonstrating the functionality of the APIs supporting both the SIO end and the GSFC end.

### *Future Plans – post 1 year IRAD –proposed funding for this effort?*

As the proposed effort will require post 1 year IRAD funding support, we plan to assist the efforts of Code 900 and 930 as identified in the letter of support for this proposal from Dr. Franco Einaudi. In particular, the Earth Sciences Directorate (Code 900) plans to submit to HQ's Office of Earth Science (Code Y) Associate Administrator Dr. Ghassem Asrar a proposal for funding starting in FY05 to continue the "Lambda Network" with the Scripps Institute of Oceanography and potentially extend the "Lambda Network" to other Earth Science collaborators such as the University of Colorado; and the Earth and Space Data Computing Division (Code 930) plans starting in FY05 to include continued operations and maintenance support for the "Lambda Network" in their budget requests for the NASA Center for Computational Sciences.

We also plan to submit a joint proposal with Ames, to Code R for FY05, as part of a cyberinfrastructure initiative, to continue part of the funding of the lambda network infrastructure to SIO. Ames and JPL also will connect to UCSD through CENIC thereby establishing a Goddard-JPL-Ames lambda net. We also plan to submit a joint proposal with Code 630 to establish a Goddard data grid to JPL for EOS and LISA data. In addition, several Goddard projects have expressed interest in taking advantage of this cyberinfrastructure and would be prepared to commit funds for the use of these capabilities if successfully demonstrated.

## Budget

There are three budget categories where funding will be required: Wide Area Network (WAN) services, network equipment, and university faculty and graduate student science application support. This IT pathfinder project will be responsible for developing the interface hardware and software to support science application testing of the first Goddard Beowulf cluster on the L-Net. SIO will commit its own resources to fund and manage the hardware and software to support the science application at the SIO end. This IT pathfinder project will fund services from the Goddard L-Net to the campus PoP at UCSD in San Diego. SIO is responsible for funding network and computing services from the UCSD PoP to the SIO application.

<u>WAN Services</u>

There are four service components that will support the connectivity to/from GSFC to SIO.

1) Connectivity service from GSFC to MAX PoP at UMCP
   Dark Fiber Lease $12,000/yr

2) MAX "experimental" services
   Lambda extension $100,000/yr*

3) Membership in MATP to use
   NLR services $100,000/yr**

4) NLR services
   <u>Cross-country Lambda Service $175,000/yr***</u>
   Total Services $387,000/yr

*The MAX is still in the process of defining its lambda provisioning services and the level of support and cost associated with connectivity to NLR. It is possible, however highly unlikely, the MAX will not facilitate Lambda connectivity to its members; hence a backup strategy has been investigated as described in the Regional Networking Approach section, but its costs are similar so this budget component does not change even under that strategy.

** Membership in MATP is required to buy and use NLR lambdas. George Mason University/School of Computational Sciences, a founding paid member of MATP, is very interested in teaming with GSFC in conducting such modeling experiments with SIO and is exploring the possibility of GSFC being a co-member and sharing the cost of membership. This could result in a reduction of this line item to $50K. However, MATP has not yet approved co-membership as a service offering to potential subscribers. If MATP decides against co-memberships, the actual cost to Goddard will be $100,000/yr for five years. Furthermore, MATP currently only offers 5-year agreements, but MATP has been contacted and informed of the Federal Government's inability to commit to longer than one-year agreements. MATP understands and is willing to work with potential Federal partners to offer one-year agreements in principle.

*** NLR, like MATP, currently only offers 5-year agreements to potential customers. NLR managed service to SIO for one 10 Gig E lambda for 5 years is $825K. NLR, like MATP, understand the Federal Governments limitations and is willing to work with potential Federal partners to offer one-year agreements.

As noted in the Technical Approach section, SIO will fund their segment of the connection from CENIC to SIO.

Network Equipment

While the ITPWG has access to some high performance network equipment, there is a need to procure additional components to support both LAN and WAN interfaces.

| | | |
|---|---|---|
| 1) | LAN/WAN Interface Modules | $38,000 |
| | Total Equipment | $38,000 |

University Faculty and Graduate Student Support

Graduate students from UMBC, assisted by faculty and directed by civil servants or the Head of the Science Data Systems Branch (Code 586), will provide support for this effort in the area of constructing interface prototypes for Earth Science modeling applications. Dr. Milton Halem, who holds a Research Professorship with the Computer Science and Electrical Engineering (CSEE) Department at UMBC as well as a Goddard Emeritus position as Distinguished Information Scientist, has agreed to serve as an advisor to a graduate student at UMBC in support of this IRAD and further to commit at least one day a week of his time to provide his scientific expertise and managerial services on site at Goddard at no cost to this IRAD. Dr. Halem also serves as chair of the ITPWG and will assist in the coordination of this effort with Dr. Larry Smarr, PI of the OptIPuter Project and Dr. John Orcutt, Deputy Director of SIO. In addition, Prof. Ray Chen, also of the CSEE Department at UMBC has agreed to make his 8-way lambda optical crossbar switch available for the year for Goddard internal experimental routing of the proposed L-Net between buildings 28, 33, and 32, and possibly 26 and 2 in order to demonstrate and test how the OptIPuter and GEON middleware can link to the ESMF to provide multi-traffic use of the L-Net. Prof. Chen will spend the equivalent of one month devoted to supporting this effort and will also serve as an advisor to a full time graduate student working on this project. Prof. Chen provides a link to the Center for Advanced Studies in Photonics Research at UMBC that is prepared to make available one of the world's highest bandwidth networks for testing with the proposed L-Net.

Schedule

NLR connectivity in the DC area is currently scheduled for Spring 04. MAX connectivity to the NLR is possible by Summer 04. GSFC campus connectivity to the NLR will be approximately 2-3

months after MAX connectivity to NLR. WAN Services and Network Equipment procurements will take ~5 months from authority to proceed.

## *Funding*

| *CY04* | *Q1* | *Q2* | *Q3* | *Q4* |
|---|---|---|---|---|
| WAN Services | 0 | 162 | 225 | 0 |
| Network Equipment | 0 | 38 | 0 | 0 |
| Prof. M. Halem | 0 | 0 | 0 | 0 |
| Prof. R. Chen | 5 | 5 | 5 | 0 |
| Graduate students (2) | 15 | 15 | 15 | 15 |
| Totals ($500K) | 20 | 220 | 245 | 15 |

Note: Funds in thousands of dollars.

## *Other Funding (Source and Amount)*

Not applicable.

## ***Manpower***

| *People* | *Type* | *FTE* | *Responsibility* |
|---|---|---|---|
| Jeff Smith (423/585) | Civil Servant | 0.3 | PI & Network R&D/Implementation |
| Pat Gary (930) | Civil Servant | 0.3 | PI & Network R&D/Implementation |
| Herb Durbeck (933/585) | Civil Servant | 0.1 | Network R&D/Implementation |
| Bill Fink (933) | Civil Servant | 0.1 | Network R&D/Implementation |
| Kevin Kranacs (933/585) | Civil Servant | 0.1 | Network R&D/Implementation |
| John Dorband (935) | Civil Servant | 0.4 | *Thunderhead* cluster mgmt and network interface |
| Ben Kobler (586) | Civil Servant | 0.1 | SAN mgmt and network interface |
| Mike Seablom & c. s. staff (586) | Civil Servant | 0.6 | ESMF/science applications |
| Weijia Kuang (926) | Civil Servant | 0.2 | GEON/network science applications |
| Prof. Milt Halem | UMBC | 0.2 | Network science applications |
| Prof. Ray Chen | UMBC | 0.1 | Network science applications |
| Graduate Students (2) | UMBC | 2.0 | Network science applications |
| **TOTAL*** | | 4.5 | |

* These figure do not include the time (estimated at 0.8 myrs from approximately 12 scientists) that the science applications civil servants plan to commit to supporting experiments utilizing the L-Net.