

Report on DTI's Live Streaming Internet Broadcast Experiments

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C.A. Christian^a, H. Wilson^a and C. Tullos^a

The Webcast Testbed experiments were initiated by the Head of Development, Technology & Innovation (CAC) to investigate and evaluate the utility of integrating video streaming technology into scientific and technical conferences, workshops and seminars. The long term goal was to identify methods creating robust webcast facilities for modest sized conferences and other events and to join the NASA-wide webcast activities as a viable member. The experiment focused on the development of video streaming capabilities to share scientific and technical presentations, and other proceedings beyond the live audience, as the events occurred. Based on our experience, we recommend the technology be expanded to public lectures and events. We further recommend continued experimentation with mobile facilities and a capability accomplish some video editing on the fly. We successfully demonstrated archived streamed events also are useful to the target communities. The experimental archives include audio, video and presentation materials associated with the live activities and augmented with textual, graphical and other multimedia materials contributed by the participants and the staff.

Introduction

The Space Telescope Science Institute (STScI) hosts many events including scientific colloquia, technical seminars and workshops, public lectures and an annual scientific conference each spring in addition to a variety of internal activities. Scientific topics for discussion are chosen by the STScI scientific staff with the motivation to provide a forum for discussion on current "hot" research areas in Astrophysics. Technical forums cover mission operations, instrument calibration, software development, mission planning and scheduling and other subjects related to the operation of Space Science missions, especially as relevant to the operation of the Hubble Space Telescope. In addition,

STScI is part of a larger NASA community that hosts events on a variety of subjects of scientific, technical and public interest.

A strategic goal for the Institute is to provide scientific leadership and become more influential in mission development on behalf of the scientific community. Our vision motivating the experiment was to contribute to the establishment of STScI as a vital scientific and technical conference center. We believed that holding relevant conferences at the Institute, broadcasting them and archiving the proceedings, could facilitate improving our communication with our various commu-

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nities. We also envisioned that participation in the wider NASA community as a viable provider of technical and scientific streamed material gives us strategic visibility and credentials in an important political and technical arena. Our prior experience with cursory tests at STScI indicated that the technical community was quite receptive to using webcasting as a viable means for remote participation (also c.f., [1]). The value of webcast technology in other scientific disciplines had been demonstrated as well [2].

We created the video streaming (webcast) testbed to broadcast major STScI events. The first externally accessible webcast was associated with the 2001 scientific spring symposium on *Dark Matter*. We anticipated that in addition to scientific proceedings, further potential could be realized by experimenting with STScI technical conferences. We were surprised and delighted to discover a supplementary demand from the STScI staff for webcasts of internal events. For example staff members enjoyed a short webcast regarding the roof repair on the Muller building and other such informal local “newsy” events. We also have been asked to support testing of webcast for tutorial purposes but have been unable to meet this demand due to our strained resources.

The long term “archival” and “publishing” aspect of this project tested our premise that the webcasts have a reasonable shelf life and value beyond the live events. We eventually wish to investigate the possibility that target technical communities might be more amenable to supporting webcasting through a fee structure. We also intend to expand our experiment to study the feasibility of providing an agile, mobile webcast facility for STScI and possibly Johns Hopkins University Physics and Astronomy events.

We describe our detailed results for the first symposium webcast in our report

“Report on Conference Live Streaming Internet Broadcasts Case Study I: The Dark Matter Symposium Webcast” [3]. See also the related report by the NASA Integrated Action Team (NIAT: [4]).

In this document we detail the experiment, and our results. We also provide recommendations for future webcast support. These recommendations are imbedded in context in the following sections and summarized briefly at the end of the main body of this document.

Bottom Line – Results

Our web cast experiment successfully delivered conferences, seminars and colloquia to science and technical users. Feedback from viewers and authors resulted in high praise for the live webcast and the associated archive. The latest example was the webcast and archive of the 2002 Spring Symposium, *Astrophysics of Life* that served as a good reference for the subsequent *BioAstronomy 213* conference.

The demand for webcast support in one year grew from mild interest to saturating our capacity to produce webcasts and archive the materials.

We were pleased that our idea to set webcast viewing at a remote site in a classroom or auditorium and allow it to run for long periods was well received by professors and students. Feedback *via* email and conversations suggested the webcasting was quite useful for educational purposes in universities.

We learned to improve our time to deploy the archive after live events from several weeks to a few hours.

We now assess that our capabilities should be more robust and pursue new avenues of study such as mobile support of events.

We have accrued considerable experience that we encapsulate here so that STScI

can provide contiguous and high quality support of webcasts in the future.

We determined that webcasts are most useful when integrated into a relevant website containing rich informational and background materials.

Experiment Context

We intended to investigate whether delivery of video streaming to the scientific and technical communities was a useful resource. Our prior experience demonstrated that webcasting was popular with public audiences [5]. We knew that delivery of "broadcast quality" video would not be possible given current bandwidths available to typical internet users but we were unsure whether technically oriented users would tolerate the slower delivery rate. We found previously that public audiences, especially students, adapted well to different video rates and interruption in service ([5], [6]). Nevertheless we wished to explore methods for providing useful material to remote viewers of live events and archived materials.

Establishment of technical requirement and proof of concept

We drew upon some of the experience of prior webcast events ([5], [6]) to design our initial experimental setup. We also joined the NASA wide pilot video-streaming group and participated in several events by re-broadcasting feeds provided to us. Through cooperation with that group, we improved our understanding of user needs and our facility requirements and further leverage that group's experience with our own.

We ascertained that we initially needed at least a 400MHz for the producer and server capabilities. Later we realized we needed considerably more horsepower and evolved the machines to 1Ghz machines. The producer handles the encoding and creation of the digital stream,

while the server responds to user activation of the hypertext link to a RealPlayer file.

At first, we configured our testbed from surplus parts. We then assured that our server was functional and matched our expected user needs. We tested our infrastructure by webcasting technical meetings and scientific seminars internally to STScI staff. We also had an opportunity to webcast the Advanced Camera for Surveys Workshop held a week prior to the first Spring Symposium (April 2001).

We enlisted staff members using different platforms to view the webcasts and provide feedback during the test periods. We documented problems and information that users would need to successfully access the events. We then further refined our system to respond to their feedback. PC users were set-up the most easily. Unix and Mac users were more problematic. Unix users in particular were hindered by an inability to install their own software and in some cases by lack of availability of appropriate client software.

We found that we needed a supplemental, easy to navigate website containing information on webcasting, installation notes and support information. We discovered that we needed to devote personnel not only to preparation and production of the webcast, but also to real-time troubleshooting. The routine in-house software/hardware assistance response time characterized by several hours or days was unacceptable to users.

Implementation

Coordination

Coordination With Host Division

DTI coordinated all webcast logistics with the STScI division hosting the event. For the first Spring Symposium, we initiated

discussions concerning the webcast experimental project with the Head of the Science Division eight months before the symposium. We later met with a member of the Local Organizing Committee as plans proceeded. For subsequent conferences and activities the timescale for coordination grew shorter over the life of the experiment. By May 2002, internal staff essentially expected “webcast on demand” for their events, a service we were not able to meet with our scant resources and other time commitments.

We quickly established ground rules for events:

- * The webcast should not compete with meeting attendance or meeting registration. Therefore, we agreed to delay announcements of externally available webcasts until a week to ten days before the event. We also attempted to provide support that was non-invasive and transparent to the symposium logistics
- * Event hosts were responsible for principal interactions with audience and speakers.
- * Event hosts were responsible for creating a link from their promotional website to the DTI website location for the webcast.

Identifying the End Users:

For each venue we wanted to insure that adequate support would be available for the variety of end users accessing video streaming materials. We anticipated that our end-user base would comprise:

- * Interested individuals who could not attend the symposium or workshop
- * Individuals who missed part of symposium
- * Educators, students and individuals in other educational settings
- * Science and technical writers

- * NASA Headquarters and Center personnel

We anticipated that the likely users of the *archived* materials would be attendees, the speakers, the organizers, the astrophysics and technical communities interested in the particular subjects covered, interested public, and some science and technical writers and press.

Infrastructure

Hardware

Figure 1 depicts the original infrastructure we deployed. At the heart of the webcast infrastructure were two desktop PC's. One Dell 400MHz Dimensions PC with 256MB of memory functioned as the RealPlayer⁷ server, providing the audio/video stream to the Internet. The second machine served as the Producer, assembling and encoding the stream for the server. The Producer originally was assembled from a Dell 400 MHz machine with 256 MB of memory outfitted with an Osprey 100 video card and a Soundblaster Live Audio card for audio input. We found that the Producer could not encode fast enough so one of us (H. Wilson) loaned a 933MHz Dimensions PC with 512MB of memory to the testbed. Eventually we were able to upgrade the producer to a Dell 420 Precision machine with dual 1GHz processors, 1GB of memory augmented with the Osprey and Soundblaster cards. The server was upgraded to a Dell 420 Precision with a 1.3GHz processor and 1GB memory.

Initially, the server machine was not intended to be a dedicated machine for the event. We learned quickly that other processes appeared to conflict with the server functionality and reliability, so we modified our configuration. Our experience with this server results in the following recommendation:

⁷ RealNetworks

Recommendation: a dedicated machine is required to adequately support video streaming. A backup machine for uninterrupted service is highly desirable.

Speakers have several choices for their presentations. The most effective presentations for providing a very good experience for both live and webcast audiences were those presented in a program like Microsoft Power Point from a laptop. We offered the option for speakers to use their own personal laptop computers,

box, and the document viewer allowing a smooth transition between presentations. The output from the chosen laptop or document viewer feeds a video signal to a scan converter. For presentations on transparency viewgraphs, we fed the signal from an auditorium camera to the scan converter.

We found that audiences do not prefer to view transparencies or paper projected by the document viewer. We realized that device was quite useful from a webcast

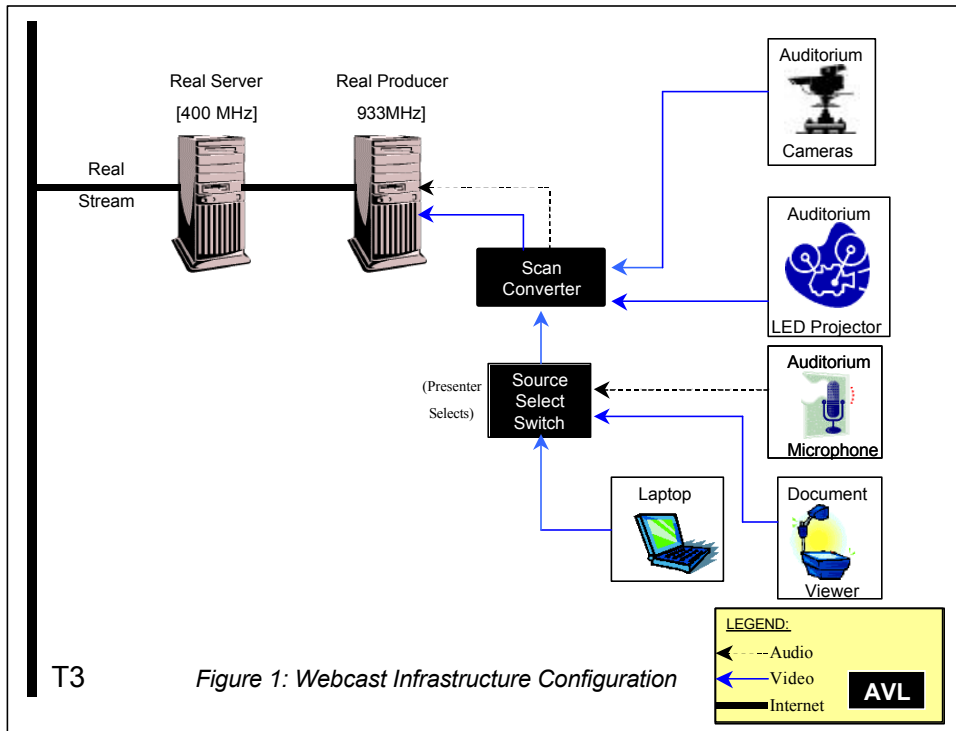


Figure 1: Webcast Infrastructure Configuration

download presentations in advance to a DTI laptop or bring the presentation on CDROM. Alternatively, speakers could use a conventional overhead transparency projector, or a document server allowing use of paper or transparency hardcopies that feeds *via* video to a projector in the meeting room. A few speakers used slides, but interest in that option recently has dwindled significantly.

For the digital or video input (laptops or document server) we easily could switch between various laptops, using a switch

standpoint because it provided video output that can be converted to a digital signal. However, the illumination of transparencies is unacceptably dim and the video output, when projected onto a screen for the audience, appears sluggish due to the video latency. We were surprised to discover that authors with hard-copy (paper or transparencies) tend to repeatedly touch and move slightly the viewgraph during presentations, exacerbating the blurred appearance of the projected images.

For each event, we needed to provide a mobile camera or access an existing installed device at the event location. We fed the camera video to the scan converter. This feed provided a view of the speaker during transition from one speaker to the next, during the question and answer period, and during presentations in which the author chose to use overhead transparencies rather than digital input. Therefore, throughout any event that featured more than one speaker, such as the 4-day symposia, a human operator was required to switch between the camera view and the digitized video (if used by the speaker). Regrettably, it was not possible to retain an individual for the entire time to make these transitions occur smoothly for each speaker. A suite of microphones fed an audio signal to the scan converter through an audio panel in the auditorium.

During discussion periods, breaks and transitions between speakers, we displayed “slates”, that is, static images to keep the webcast viewer informed about the proceedings. We found that the slates should come up promptly as needed and be removed an instant before a speaker is being introduced. Although we realized this was a thankless task, and requires keen attention and understanding of the symposium proceedings, the smoothness and professional appearance of the webcast justifies the resource.

Recommendation: Speakers should be encouraged to use a presentation program such as Power Point from a laptop computer.

Recommendation: Webcast support should include the availability of a high performance laptop for speakers to download presentations from the network or access materials from a CDROM.

Recommendation: A switch box to select various devices (several laptop computers, a document server and other devices) should be available for smooth transitions between speakers.

Recommendation: Any future Webcast support should include publication of “recommended practices for presentations”, for example see those compiled by DTI [7]. These recommendations should be sent explicitly to speakers approximately 2 weeks before the event.

Recommendation: An A/V producer should be present and attentive throughout all proceedings involving multiple speakers to quickly switch between the wide angle camera view, zoomed camera view for transparency viewgraphs and the digital input device.

Recommendation: An A/V producer should be present and attentive throughout all proceedings to facilitate smooth and timely switching between slates and the live proceedings.

Internal/External Broadcasting

We configured our infrastructure with considerable attention to external users. We relinquished optimization that would have enabled our internal users to have a superior webcast in favor of providing a useful stream for external users. For example we downgraded our frame rate from 30 frames a second to 15 frames a second and used the lowest resolution available (320x240) for the video stream.

Our focus on **external** users reflected our vision to enable STScI to become a full service state-of-the-art conference location. Further, we intended to study the usefulness of webcasting for scientific and technical audiences, emboldened by the knowledge that the technology was well received by the public.

Nonetheless we regarded internal users as a key audience segment.

Multicasting/Unicasting

The version of RealPlayer we adopted allowed us to produce both unicast and multi-cast video streams. A unicast transmits packets to a single destination. A multicast is configured to deliver streams to a set of clients that are configured as

members of a multicast group. The client and server machines do not need to be geographically collocated. The advantage of a multicast stream is a more efficient usage of bandwidth. Unicast allocates bandwidth for each connection where multicast does not. At the time of the first event (Spring Symposium 2001), we had not fully tested our multicasting features and so we opted to use the tested unicast mode. Multicasting also requires the various networks it utilizes and the associated routers to be configured for multicast. Therefore, while we can participate in multicasting within the NASA community, multicasting to a collection of geographically separated external users is a formidable coordination task.

Streaming Technology

The video streaming technology has many facets including production, serving, streaming and client access.

We selected RealNetworks as our platform for video streaming due to the wide availability of the free client software, Real Player from Real Networks. Real Player is used either as stand-alone software or as a plug-in for a browser such as Netscape or Internet Explorer. RealNetworks was the first company to market a streaming product and one of us (CAC) has used it for internet broadcasting since its emergence in 1994. Real Player remains the dominant streaming platform across the Internet.

For production and encoding we used Real System 8, later upgraded to version 8.1. It includes Real Producer Plus, Presenter and Slide Show. The software allowed us to create media clips from the selected video source and audio from the auditorium microphones. The serving tool used is Real System Server 8. The server package streams the media file to the client players in unicast or multicast (or both) broadcasts.

We elected to take advantage of the SureStream feature in the server that allowed us to encode one file for multiple bandwidths. The advantage to this approach was that we did not need to create numerous independent streams at varied bandwidths. We were able to make live presentations available to those on an internal LAN (10Mbit) as well as to external users accessing the server with throughput as low as a dial-up connections (28.8K and 56K).

The bandwidth was limited to 10Mbit link by our network department. This was to ensure that we did not flood the outside network connection so that other Institute business could continue uninterrupted. At our highest peak throughput, we sustained 5.8Mbit traffic, and this rate served 46 client players at a 150Kbit frame rate. In principle, throughput can be optimized for the number of users, bandwidth and the frame rate, and balanced with the other demands such as operations, archive, public access and other Institute services to external clients. The resolution of the video we offered was 320x240 using the color format YU V12 planar. In the future, the resolution can be varied, as bandwidth to external users increases and streaming capability expands.

Recommendation: The video streaming output should be tested, evaluated and optimized for the target audiences. Different audiences will have different requirements. Internal users demand higher resolution while lower resolution and varied frame rates will be appropriate for external users.

We realize that the value of video streaming lies not only in the producing the live event, but also in the archive of materials. Therefore, we placed importance on capturing a high quality video recording of the proceedings so that errors and drop-outs can be corrected after the fact, improving the integrity of the archive material. This activity placed an additional load on video streaming personnel, in addition

to insuring the live streaming occurred and “instant” help was available to users.

Recommendation: Support of video streaming must include availability of personnel for fault-proof continuous streaming, real time response to problems encountered by users and producers and attention to capturing suitable materials for archival purposes.

Platform Software

We equipped our testbed computers with the Windows 2000 operating system and Microsoft Office (for messages and to receive speaker presentations). We used Adobe Acrobat to convert presentation files to PDF files for publication in the archive. We also used the Macromedia web developers kit for our initial web design, after an initial attempt with ZOPE. Subsequent design by ourselves and an outside contractor was accomplished with similar Macromedia software. We used Adobe Photoshop and JASC Paint Shop Pro for creating slates.

Webcast Client Software

Client Registration

For the first external webcast (*Dark Matter*, April 2001), we elected to encourage webcast users to register in advance so that we could estimate the number of streams required and the load on the infrastructure. Through our active participation in the NASA video streaming working group, we have the opportunity to request additional support, if additional streams are necessary. We needed to reserve them from the NASA group, since the other sites, as ours uses precious resources to insure continuous webcasting especially for extended events like conferences. The additional streams would be available through a technique called *splitting*. In splitting, the source media server sends digital streams to additional splitting servers that in turn serve the webcast to the end users. We have participated in

NASA webcasts as a splitting server for several projects and the results of those activities are recorded by the working group.

Registration can serve as a tool for anticipating the operating systems to be served during a webcast, and providing relevant information to users before the symposium so that access to the webcast would proceed smoothly. We captured the registration information in a Sybase database and documented the results of the registration process in our prior document [3]. For subsequent webcasts, we did not use registration and it does not appear that it is necessary for providing adequate support. We note that we did find that client registration was a valuable tool for persuading users to test their configurations in advance and to alert us to any problems before the symposium initiated.

During the first Spring Symposium we were able to determine the types of machines our users employed to view the webcast. The dominant operating system was Windows, primarily Windows 98 augmented with Windows ME, 95 and Windows 2000. A few users intended to use the NT operating system. Four users reported they would use a MAC. Sixteen users registered Unix type operating systems including Linux, and various versions of Solaris.

In 2001, users had computer processor speeds varying from 300MHz to 866MHz, and system memory ranged from 64MB to 1GB, where the majority of users had access to 128-256 MB of memory on their machines. We know that computer capabilities have evolved in the past year. However we decided not to use registration to poll the types of machines in use. The Real Player logs do contain some information in that regard but the logs need to be edited by hand or through expensive analysis software and neither was available to us during the experiment. Note that some members of the NASA

video streaming group do have access to such sophisticated analysis tools through costly contracts.

Recommendation: If computer configurations are of interest to optimize support to external users, more sophisticated analysis of webcast logs will be required.

We were pleased that some (mostly university) users viewed webcast in a group setting (classroom, or other situation). These users left the machine on with a projection system, so individuals could join the conference periodically throughout the day.

Monitoring Client Connections

In the early stages of our experiment we monitored the number of users, the bandwidth and the throughput during webcasts. We used the RealSystem Server 8 with real time monitoring utility as well as a running log file. The real time tool reports the servers CPU and memory usage. Also the amount of bandwidth used by the clients is reported along with the number of clients connected. More recently we use the monitoring tool only if we believe problems have occurred such as reported slowness or image "blocking" due to a mismatch of stream and client software settings.

Given sufficient time and resources, we could monitor, in real time, the IP addresses of the clients, their connection type (we provided only the Real time streaming protocol, rstp, rather than FTP or other block transfer protocols), the duration (length in time) the client accessed the webcast, and the name of the file they were accessing. Users connect to the archival RealPlayer files, so we needed to distinguish between the live stream access and archive. The recorded log file gives similar but not identical information including the type of browser and version a particular listener used.

Other Streaming Technology

We implemented RealPlayer software because it is the most pervasive product for video streaming on the Internet. We ran trials with QuickTime and Windows Media, with unsatisfactory results. We encountered confines on I/O resource use and other limitations and restrictions. Note that neither product requires licensing, and, except for issues regarding STScI specific hardware configurations that have limited support, have an advantage that they are free, and so would be attractive alternatives in the long run. Real Networks products have an expensive licensing fee for the server. Our use in DTI was limited to 100 stream servers.

Though economically attractive, Windows and Apple products are only in their infancy, while the Real Networks video products are in their seventh year and have market dominance. A poll conducted by "Network Computing" in early 2000 indicated that 62% of streaming users employed RealNetworks, 25% used Apple Quicktime/Darwin streaming and 10% used other such as MBONE. Of PC users, 70% also use Microsoft Windows Media. By 2002, Key Labs¹ reported Real products were favored 16:1 over Windows Media. In the future though, it would be beneficial for users if our streams could be made available in several formats, especially for the archival files.

The first RealPlayer (video) was released in 1995 and there are now over 300 million unique registered users, with 200,000 new users per day. By 2001, more than 85% of Internet web sites used Real products (Audio, Video and G2 with Flash).

¹ <http://www.realnworks.com/company/press/releases/2002/keylabs.html>

User support

During all events, DTI provided immediate support to users. We provided an extensive web page and help file with answers to frequently asked questions regarding the client software and webcast logistics. We also serviced phone calls and email sent to dtihelp@stsci.edu and to each of us individually.

The most common problem encountered by the users was in the setup of the RealPlayer. We assisted users in selecting an optimal throughput, setting "buffered play" rather than downloading a whole Real file at once, and other similar situations.

Some assistance to users was supplied by the Computer Support Office for users requiring help in installing the Real 8 version of the client on Sun Ultra Workstations running Solaris 8 operating system. This was rarely possible on an urgent basis, however.

On our web page, we provided explicit instructions to users for downloading the Real 8 client because we wished to provide more straightforward instructions than those on the RealNetworks website, particularly for the free client software. The specific client version we have been recommending was RealPlayer 8 free player. RealPlayer operates as a plug-in component to a browser. Although we obviously have no control over the RealPlayer version updates available to clients, we were able to suggest that clients configure their players to "warn before automatically downloading and installing" new software by selecting that option on the download form.

DTI Webcast Web Site Development

Website Content

We created a website to serve the following user needs:

- * DTI entry point. We provided a top-level entry point to access all DTI services and products (Figure 2). We linked live webcasts through a "highlights" area on this page, and through our "projects" pages. We negotiated for links from the host conference or event website and we requested links from the top STScI site.



Figure 2: Website with webcast links

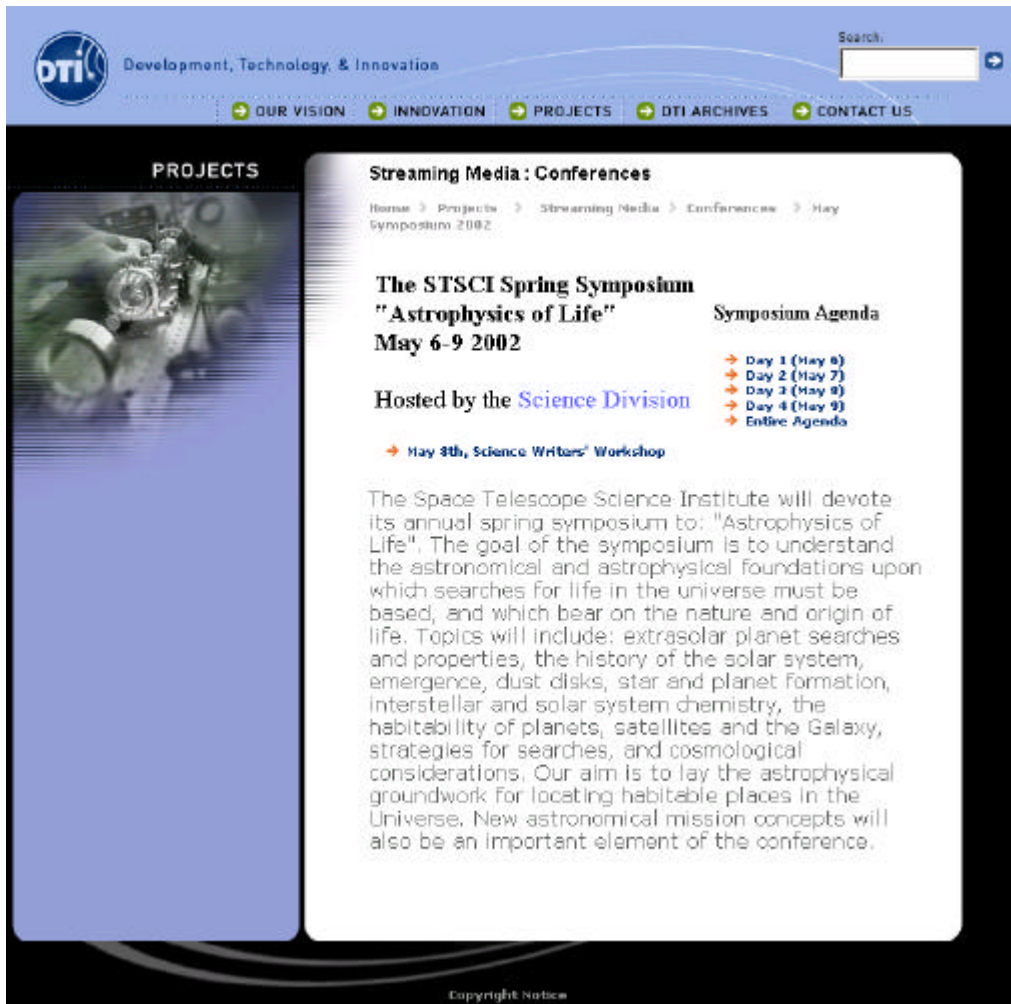
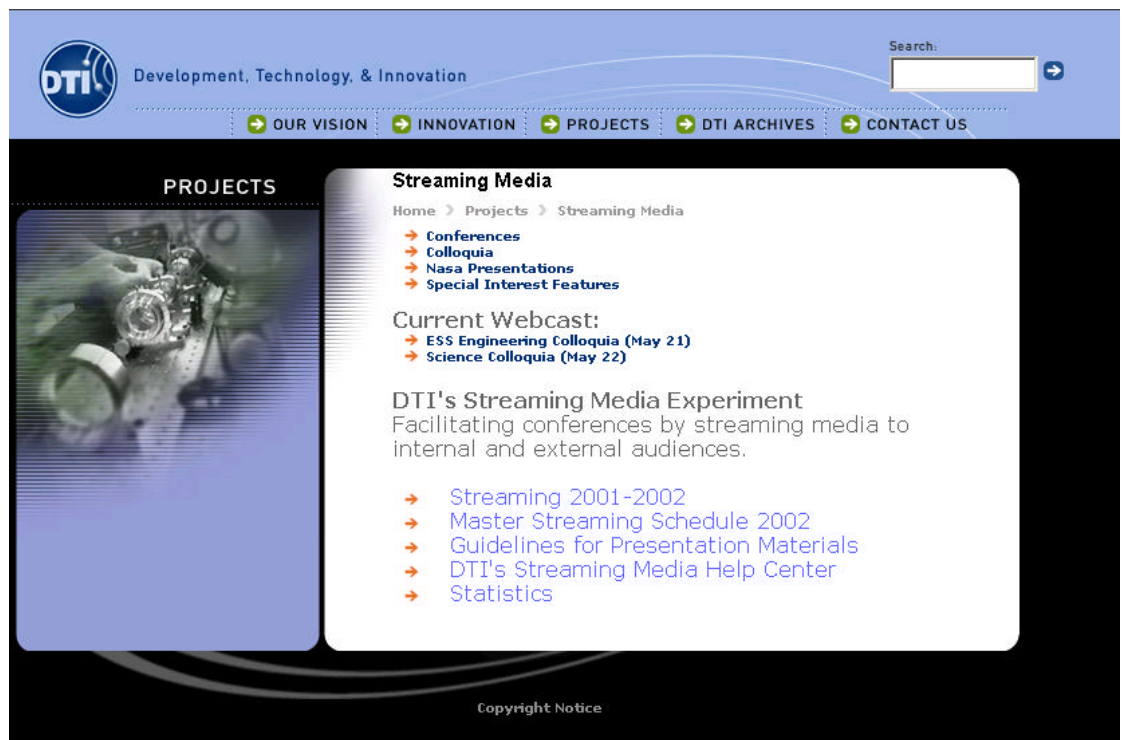


Figure 3: Event specific webpage

- * Live webcast entry. We created a custom webcast page for each event (c.f., the page for the 2002 Spring Science Symposium, Figure 3). The “page” contained a link to the relevant RealPlayer files, a registration page (if used), and to the main symposium website created and supported by the host STScI unit (e.g., the Science Division in Figure 3). News and updates regarding the video streaming appeared here also. We designed this page and the event schedule page (described below) to serve the live event and provide easy re-linkage to the archive pages afterwards.

functionality and a method for obtaining help as well as video streaming download information. These links were available from the event pages during the live event, and with a website redesign, we incorporated the links on the *Streaming Media* Projects page (Figure 4) so users could find the material easily.



- * Help and

Figure 4: Streaming Media Projects Page

Feedback: We provided feedback

- * For every event we provided the detailed schedule, with the author supplied titles, abstracts (if requested by the hosting division) and links to the webcast. Once moved to the archive, the event schedule page also included presentation materials (power point or scanned viewgraphs). Users linked directly to the webcast stream from this area, as well as from the main event web page and, during the event, from the top DTI page. We also designed this area to facilitate movement to the archive, so that the appearance and functionality would be stable for users.
- * User registration. For some events, this area captured potential user information and software configurations for statistical purposes and to anticipate user needs. We enabled user registration approximately ten days before the event, and alerted potential users *via* an email notice.
- * Presentation Format: We found that scanning materials, as we did for the first symposium was time-consuming, costly and induced an unacceptable time delay in creating the archive. Happily, in one year, speakers overwhelmingly migrated to digital presentations and were cooperative in providing digital copies of the materials for the webcast archive.



Figure 5: Event schedule page (live event and archive)

formation including computer infor-

Security

We did not invoke any custom security or passwording for the webcast.

Testing

When we deployed our initial, draft website in 2001, we ran several tests with the Real software. We enlisted several STScI staff members to be pilot testers of the webcasting and the website. We polled them for feedback regarding sound quality, appearance, throughput, connectivity and computer functionality. Throughout the webcast experiment, we appealed to internal users to provide the most rapid and candid feedback, although we did find external users were responsive especially if they encountered problems!

Back-up Plan

We prepared a backup machine for the RealProducer and we configured it for quick exchange with the primary machine if necessary. If we had encountered a situation requiring the backup scenario, we would have been required to rapidly move the Osprey card to the new machine. Fortunately we never needed to exercise this option. Also the backup machine was not configured to SureStream because it did not contain sufficient CPU or memory for the task, so an urgent switch to the backup facility might have been troublesome.

We also configured a fairly basic computer as backup for the RealSystem Sever 8, and if we had exercised this option throughput definitely would have degraded.

There were several other potential points of failure for webcasts. We had no backup audio or video lines from the event sites (usually the STScI auditorium) to the producer machine. We had no contingency for the individual technical staff – producer, technician, and computer support or the web specialist.

The STScI auditorium video camera had degraded considerably over many years, and there were few suitable replacements for that equipment. The poor quality of the camera definitely affected the webcast appearance. For several webcasts in the auditorium and in other locations, we eventually were able to use a hand-held digital video camera on loan from the STScI Audio/Visual laboratory. Ultimately the main auditorium camera was replaced with a digital device.

Recommendation: Digital cameras should be used for webcasts, and should be optimized in real time to present the best possible video for the environment visibility.

Webcast Logistics

Pre-Meeting Interaction with Speakers and Users

For most colloquia, short meetings and other short (1-2 hours) events, we interacted with the speakers just minutes before the webcast to keep them informed of the logistics. For major proceedings such as the Spring Symposia, we alerted speakers about the live video streaming, and sent a general email promoting the webcast *via* appropriate lists of users (for example HST users). We also notified various university departments and other organizations. These notifications took place 10 days before the live event.

Equipment Preparation

For every event, we test our equipment so that the webcast would flow smoothly. For major proceedings and high profile events (e.g., astronauts' visit) we also arranged to test auditorium audio/video equipment, and the webcast did not interfere with any event proceedings. We show in Figure 1 the typical equipment available for a symposium:

- * Auditorium video camera, a Shart Professional Camera Model XC-A1, aimed at the presentation screen.
- * Document viewer and input device switcher, to allow switching between laptops and the viewer. (Usually not used).
- * Mobile wireless microphones for speakers
- * Two laptop personal computers.
- * Auditorium and Audio/Visual laboratory (AVL) audio and video equipment (switching, pointing, gains, distribution)

Infrastructure Modifications During Event

Frame Rates and Encoding

We used SureStream for encoding our 10Mb "corporate" (STScI) LAN and 56K and 28.8K dial ups. Users external to the Institute were provided a stream over our T3 line to GSFC, but speed at the client sites also depended upon the internal restriction to 10Mbs imposed by STScI, the connection speed out of GSFC, restricted to 20Mbs intermediate network speeds and the client's connection.

Usually encoding was at 15 frames / second. Attempts to encode at 30 frames per second failed until we upgraded our equipment.

We found that it was necessary to run the encoding software without interruption in order for viewers to have contiguous access to the webcast. If we had elected to create individual Real files during the event (for rapid deployment of the archive), webcast viewers would be forced to reconnect to the server at the beginning of each talk. During the first symposium, the demand on the DTI staff was high, so that accurate records of speaker start and stop times were not recorded. By

2002, having become more proficient at the webcast technique, we were able to initiate the webcast production as well as accurately record the time that each speaker initiated his/her talk. Using the recording times, explicit reference to each presentation can be made for the archive. The setting up of the hyperlinks into the Real file takes about an hour for a proficient webcast engineer to accomplish.

The convenience to the user for the continuous stream method was that there were no breaks in the broadcast, and users could tune in at any time to obtain the live event.

In the future we prefer to be able to continuously stream, but to capture each segment "on the fly" during the proceeding. We continue to pursue the feasibility of obtaining the appropriate software to assist with this task. We know that the archive could be deployed more rapidly with some presentations made available the same day. We have often had requests for access to talks on that timescale.

During major events, the A/V L engineer periodically made changes to the gain for producing higher quality video for encoding. Participation throughout webcast events by the engineer is critical for high quality production.

Recommendation: Obtain the necessary software for simultaneously providing a continuous stream as well as dividing the Real stream into segments "on the fly". The segments correspond to the individual speaker presentations.

Internet Reliability

In general, internet service to STScI is reliable, being served through Goddard Space Flight Center (GSFC). During one event, GSFC announced a connectivity outage without interacting with downstream users like STScI and the NASA Public Affairs Offices. Such internet outages would have been disastrous, but during this particular incident we were alerted

at the last minute and managed to get GSFC to agree to change the outage period.

Recommendation: Webcast support personnel should insure that GSFC is informed regarding a need for contiguous service during a web cast event so as to avoid unanticipated outages in service.

Recovery of Speaker's Materials for the Archive

For colloquia and workshops, we requested that speakers provide copies of viewgraphs for placement in the webcast archive. These materials accompany the archived RealPlayer video files. We also suggested that links to any ancillary materials of interest to the scientific community (web pages, online simulations, etc.) be forwarded to us.

We found that the electronically authored viewgraphs were easy to obtain. All electronic copies were authored in Power Point, and no other formats were submitted.

Copies of viewgraph transparencies are more problematic. For the *Dark Matter* conference in 2001, we collected copies of the presentations and later scanned them to provide PDF files for the archive. Our efforts were greatly appreciated, but we discontinued the practice due to the level of effort required (see also our detailed report on this issue in [3]). Happily by 2002, most speakers had migrated to power point or a similar digital presentation methodology.

Monitoring

We always monitored accesses to the website and to the Real Server. Real Server access is accumulated in separate log files. We also keep general log files for our web server, recording specific URLs and files accessed. For the webcast logging we use the standard Real recording software² in addition to monitor-

ing the webcast flow in real-time. The real-time monitoring is useful for anticipating problems and understanding the performance of the system.

Feedback from Users

We received user feedback, both from STScI staff and external users via email, phone calls and discussions. In general, users expressed a positive experience with the webcast, finding it a valuable experience and source of information. Users provided commentary on the positive attributes of the webcast logistics and appearance and offered many suggestions for improvement. We were delighted to have very positive feedback over the next year from the external science community. Also the viewers of the software conference were quite complementary about the availability of the webcast.

Early on, users encountered some difficulties in the synching of the video image with the audio. Users on slower links reported freezing of the video and some jerkiness in the images. Occasionally dropouts occurred and occasionally users were forced to restart the RealPlayer to reconnect to the webcast. Some Unix users encountered problems enabling the RealPlayer. With the upgrades to the test-bed equipment, these problems have diminished but have not been eliminated. Real-time help to users is critical for the webcast to be successful.

Since the earliest webcasts from STScI, users have noticed that transparency viewgraphs were often difficult to see from the camera view. Power Point slides are always more legible whether fed directly to the encoder, or through the camera. We decided to set up the auditorium camera to avoid overexposing the transparency viewgraphs. This did cause the

<http://service.real.com/help/library/guides/5server/doc/9.htm>

² See

speaker to be nearly invisible, in a darkened area on the camera.

We had no facility for routinely providing a microphone to the audience during the question period after each talk. Both webcast users and the live audience (in rooms the size of the auditorium) would find a mobile microphone or a remotely controlled microphone useful so that the full interaction of the participants with the speakers could be heard. We encouraged session chairs to have the speakers repeat the question, but they rarely did. In some instances members of the live audience spoke at some length in a dialog with the speaker and microphones would have been valuable for recording and broadcasting those interactions.

Recommendation: An operator should always be present to adjust cameras used to view transparency viewgraphs and speakers during introduction and discussion.

Recommendation: The audio situation for every webcast needs to be improved. Microphones – either mobile or boom mics – should be deployed so that the commentary of audience participants can be heard by both the live audience and remote viewers.

Usage Statistics

For the conferences we see 30+ players connected periodically. The maximum number of users we have seen during any one presentation is 56. Through user feedback we learned that quite a few sites set the webcast up in a classroom or small conference room so that students, faculty and other interested viewers could participate in the webcast, interspersed with their other activities throughout the day.

The maximum bandwidth used was 6.2Mb/second. That occurred during specific events when we saw our maximum number of connections.

Most of our users are from the United states. We have seen regular connection

during conferences from Europe and Australia, France and Germany being the most frequent of the European countries. Japan is also a frequent user community. Archives are accessed at a consistent low level rate. Conferences are accessed but we notice access to the scientific colloquia as well. STScI staff refer back to archives of the ESS engineering series.

We noted a strong correlation with number of connections and the effort we expended promoting webcasts. If we issued multiple reminders about the webcast, the number of users was higher than if there was only one or two promotional message.

Recommendation: Clearly, users will access webcasts if they are aware of them. Webcast support should include a provision for promoting webcasts regularly.

Network Monitoring

During events, we typically monitored the outbound streams, bandwidth and internal multicast traffic. We wished to have a clear understanding of the broadcast requirements and how streaming interplays with HST data (archive) access, use of scientific web resources, and public outreach materials, none of which can tolerate degraded performance.

We monitored utilization and error rates by using network “sniffers” and invoking standard router monitoring commands.

In general, this experiment resulted in no unusual load on the network or other problems impacting users.

Recommendation: We recommend that more sophisticated software be implemented to accurately trace connections, threads and the details of user behavior to better understand live and archive webcast usage.

Archive Deployment

Experience has demonstrated that a large part of the value in webcast events is the

archive materials. For the first symposium, we encountered a major hurdle in deploying the archive rapidly. The scanning of the viewgraph hardcopies was logistically difficult and time consuming, causing a delay in the integration of the archive website.

Also we experienced that the webcasts require considerable coordination between the live event facility (microphones, equipment positioning), the video engineer, and the server engineer. We also had minimal capacity with the current computing equipment for serving the streams. We encoded and served the streams as one continuous webcast. This resulted the creation of large video files since it was not feasible to start and stop the encoding and server for each speaker. Such interruptions have the ancillary effect that webcast viewers would be required to start and stop the client software for each presentation.

The large video files took many hours to review and dice into logical segments for each presentation. In some cases individual files were created, while in others, access to a particular segment was accomplished through a specific time reference being included in the link into the video file. Each segment then was linked to the speaker's name in the symposium schedule and the viewgraph files if available.

We deployed the first archive three weeks after the symposium proceedings. Our publication record as considerably improved and by the May Symposium 2002, we were able to link to the archive by late the same day or the following day. However we needed the webcast engineer to monitor all the presentations, carefully noting start and stop times. In the future, it would be advantageous to have improved server capabilities so that a continuous stream could be served and each segment could be split off for rapid creation of the archive.

Conclusion

Was It Successful

We believe that our experiment webcast was a success, according to user feedback. Our additional measure of success is that most conferences and workshops increased their participants by about 20-30% due to the webcast. Also, we have noted that the archives of nearly all events have a sustained viewership.

The administrative, technical and science interfaces were successful. We have been able to produce webcasts with few technical difficulties. Users experienced a few server halts, remedied by restarting the software and some logistic glitches. Participants and remote viewers report to us that they find the presentations useful, although camera views of speakers could appear better with improved camera quality.

We noted that the demand for webcasts grew from occasional interest to a full schedule, sometimes with more than one webcast per day. The success of this webcast experiment proved to us that STScI has the capability to develop the technical talent to provide video streaming as a regular part of its communications strategy.

We conclude that we can deliver Internet bandwidth consistently to a limited number of end users, using a variety of distribution techniques. To increase our capacity and the quality of the broadcasts we will need sufficient and diligent technical support.

Technical components

The individual technical areas were:

- * Receipt of video signal from the auditorium - **successful**.
- * Conversion of video signal and encoding - **successful**.

- * Distribution of converted stream to internal and external users - **successful**.
- * Use of RealPlayer client on user desktop systems - **successful** but Unix systems were more problematic. End users had some difficulties with configurations and installation.
- * Server performance – initially **moderately successful**. We procured dedicated machines for production and encoding which improved our success. We recommend a robust back up infrastructure.
- * Deployment of the DTI webpage in concert with the symposium webpage for access to pertinent information and distribution of the webcast – **successful** and useful.
- * Conversion of video following presentation into .rm format - **successful**.
- * Creation of the webcast files for the archive: - **successful** but initially slow. Through continual effort in monitoring the proceedings we were able to shorten the archive deployment time, but recommend using more automated procedures. Obtaining additional hardware and software capabilities for handling and encoding the video stream would allow us to stream continuously but also select stream “chunks” for rapid deployment of the archive.

Lessons Learned and Recommendations

As a result of the experience gained we have compiled the following recommendations:

- ?? We recommend that the division responsible for the webcast manage all logistics of the event. Multiple promotions of the webcast should be included.
- * Speakers should be informed early of the webcast. Issuing guidelines to the

speakers can optimize the appearance of presentations for webcast viewers and the live audience.

- * We found that the use of the webcast by groups (setting up one computer in a public area for anyone to view) was a very successful and well received strategy. Several groups have subsequently asked to be informed of future tests and events as a result of their experience.
- * High quality video should be recorded for backup to create high quality original files for the archive, should the producer or server machines fail during the live event.
- * A generic laptop PC should be available for author use to download presentation materials *via* the Internet or CDROM.
- * We recommend a full time producer and attendant during the live events for smooth, consistent operation.
- * We believe the transition from the live presentations to slates and camera shots should be consistent and smooth throughout the production.
- * We recommend that an engineer or producer be available continuously to adjust levels and other parameters for the best quality video.
- * A boom microphone and/or audio equipment that allows live participants and remote viewers to hear audience dialog is essential.
- * The retrieval of hardcopies and conversion to digital files can be abandoned. The process is too time consuming and difficult.
- * We learned that an easily navigable website is essential for assisting users. The support website should include software download information, answers to frequently asked questions, troubleshooting information and sug-

gestions for best individual or group viewing (with PC and projector).

- * We found that unless users are intimately familiar with the subject matter, additional web resources should be available (c.f., the STScI press release website). Ancillary materials, in addition to the information on the technical set-up is valuable and should be retained with the archive.
- * We recommend that real-time rapid help be available to users during the live event.
- * We do not recommend the use of user registration for most events unless demand exceeds our capacity.

Future Activities

We intend to improve the facilities and logistics of conference webcasting to create better virtual experiences for remote users, based on our lessons learned. In addition, we would like to explore opportunities for providing a mobile webcast studio with video editing capabilities (for slates and other effects). We believe we can improve the mobility and agility of our webcast facilities so that we can rapidly deploy and support other events.

We also wish to pursue methods for including the remote audience more interactively. In addition to email, we would like to make live audio interaction a possibility.

We would like to instill a culture in the science and technical community to provide additional multimedia resources linked to the presentation materials.

We would also like to improve the mobility and agility of our webcast facilities so that we can rapidly deploy and support other events.

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Appendix A: Webcasts Used in the DTI Experiment/ evaluation of Video Streaming

Chronological Order (all webcasts split with NASA Ames)

NASA Integrated Action Team (NIAT) Report, January 11, 2001, NASA Administrator Dan Goldin's webcast – The first NASA-wide webcast from the administrator. This was our first webcast with the DAT5K group

STScI Science Colloquia – Weekly 2001, 2002

Dark Matter, STScI Spring Symposium 2001 (split with DAT5K). Included a delayed webcast recorded in Bloomberg auditorium 4/2-5/2001. (Slates added)

Shark Cage I newscast reports. June 2001 Most live news casts in the beginning, some pre-recorded at the end of the project.

NASA Robotics – Ames - (split for DAT5K)

STScI Software Workshop, fall 2001 (Slates added)

STScI Popular Talks – monthly (occasional by special request)

NASA Robotics – Headquarters - (split for DAT5K)

SM3A – STScI events, and in collaboration with San Francisco Exploratorium, *Origins and Observatories* project.

STScI/OPO and NASA produced Space Science Updates

NASA live hurricane fly through (split for DAT5K)

NASA Robotics – Langley -- (split for DAT5K)

ESS Colloquia (some requested to not be broadcast)

Open Night at the Institute (occasional, by request)

Science Staff Candidates Colloquium Series

Shark Cage II reports 2002. (all prerecorded)

SM3B entire mission with the exception of one day - highlights

AURA Software Workshop 2002 (Slates added)

SM3B Astronaut visit – Live webcast from the Bloomberg auditorium

New NASA Administrator Sean O'Keef address to NASA and all contractors (split for DAT5K)

Astrophysics of Life – May Symposium 2002 & *Science Writers Workshop* (split with DAT5K)

Former Administrator Dan Golden presentation at STScI

NASA Robotics finals

Experimental Details of Webcasts

Additional detailed information is available for these i.e., what resources were used, and statistics for the major events.

Administrator Goldin's NIAT webcast – This was also the first webcast we did in collaboration with the DAT5K group. We tried several splitting tests were tried. Te DATT5K looked at outsourcing this to Akami due to Administrator Goldin's requirements for 150 KBPS 20 frames video. The webcast originated at HQ and split from there while being sent to Akami. NASA provided all promotion of the webcast.

Within the NASA ATM network the video and sound quality were very good. Several sites including STScI experienced problems when getting the link (the Real stream not the split) from Akami. The problem was traced to external Internet traffic and the need to pull a stream from the internet into the NASA ATM cloud. In the end, Akami was not used and we handled the streams within the centers on our own. Administrator Goldin was very pleased with the outcome.

Science Colloquia – Weekly – These events have been an excellent test for webcasting. We encountered many interesting challenges with the diverse speakers. Most of the issues regard the appearance of most presentation materials in a streaming environment. As a result of our experience, we now provide a presentation guide for multi-media presentations for webcasting. Note that live audiences also benefit greatly if presenters use the guidelines.

Dark Matter Spring Symposium 2001 – This webcast was split with DAT5K). The event included a delayed webcast – recorded in the Bloomberg Auditorium. The results of this experiment are documented in detail under separate cover [3]. Many external scientists expressed kudos both verbally and in email for this experiment. The archives are still used as this topic is an active one in the astronomical community.

Shark Cage 1 6/2001 – We produced mostly live newscasts in the beginning of the project. Later we pre-recorded them for smoother presentation. We accrued substantial expertise during these live webcasts, similar to best practices in broadcast television. We tried 3 types of microphones and 2 types of cameras. (see Sharkcage 1 notes for specifics) . We did some improvisational activities, such as playing instruments, and having fun commercials. These improvisations were received with mixed review. We did not attempt any live newscasts for SharkCage 2 as they required considerable effort. We felt the pre-recorded webcasts were smoother than the live webcasts.

We used several different cameras on loan. The best camera was a digital video camera graciously loaned by an STScI staff member (O. Lupie). This camera worked very well. We also used a loaner older camera from the Office of Public Outreach. This was less successful . We found the video image was not as good as the other camera and the microphone was poor in performance.

NASA Robotics (split for DAT5K) – We configured the server ports for stream receipts. We cannot author and re-stream simultaneously from one machine. The Robotics streams originated at Ames, one at Headquarters and one at Langley.

STScI Software Workshop - For this event, DTI staff operated the STScI sound board during this event. An A/V Lab staff member (E. Weibe) added slates (static graphical images used as separators between speakers and during breaks) via the Amiga Toster. We found the production flow to be erratic. Our recommendation is for smooth video streaming an A/V producer is required to continually monitor proceedings and rapidly respond with camera views and slates. This individual needs to be in contact with all other staff involved in the webcast production.

Popular Talks - We produced webcasts of popular talks periodically, based on demand, subject matter and our resource loads. In general, we found that the speakers for popular talks presented well prepared multi-media materials. No slates were involved and no promotion was required other than an all staff email. We initially needed to adjust the sound was balanced and then the system ran autonomously.

Office of Public Outreach (OPO) -- NASA Space Science Updates - Initially OPO wanted to send out both a slow bandwidth stream and a high bandwidth stream but without dual stream capability. Many of their users are on slow connections (reporters, educators). The problem OPO encountered was that encoding at the lowest possible common denominator, 28.8Kbps, users on a 10Mb Lan suffered through freeze frames and throughput blocking. We built our server to encode multiple streams. One file can serve streams at 28.8Kbps, 56Kbps and 10Mb Lan speeds. Considering our capability, OPO requested DTI support for the NASA SSU's.

NASA Live Hurricane Fly-through - (split for DAT5K). NASA set up streaming ports and a "Stream Genie" was used to broadcast from aircraft and broadcast to one of the NASA sites. The DAT5K picked up the splits from that site.

ESS Colloquia - DTI was asked to support webcasting of the ESS Technical Colloquia. In general we planned for public distribution, but some authors requested internal webcast only. ESS promoted the webcasts. We provided light protection of the webcasts by providing ESS with an explicit URL, but no link from the main DTI website. The technical speakers appeared not to use the recommended guidelines for presentations so that most of the webcasts were usable only for the audio. The video appearance of the materials was poor for webcast viewers.

Open Night at the Institute - We set up links for the evening public talk at 5pm. An operator stopped the encoding at 10pm. This was our "auto pilot" test. The speakers needed no support for their presentations other than that provided by the OPO staff member hosting the Open Night. In general, we found that the materials were of excellent quality largely because they were prepared for the general audience. The following day the Real files were pared down to contain only the presentation before the file was inserted in the archive.

Shark Cage 2 - The newscasts were infrequent, scripted and prerecorded. The recording was accomplished with a DTI staff member's camera and microphone (C. Tullos). The result was a more professional appearance than for SharkCage 1.

Servicing Mission 3B - We webcast the entire mission highlight series except for one day. We captured the stream from NASA TV.

Aura Software Workshop 2002 - DTI staff (C. Tullos and H. Wilson) operated the sound board with production similar to the STScI Software Workshop. We attempted to split streams with NOAO (M. Newhouse) but the facility there precluded our success.

SM3B Astronaut visit - We produced a live webcast from the Bloomberg Physics and Astronomy auditorium. As an improvement over the Spring Symposium situation, DTI was offered access to a audio /video line fed from Bloomberg to STScI. We made use of the Bloomberg facility lighting and sound system. Speakers tended to be mobile and for an optimal webcast, we would have required active camera support.

Science Staff Candidates - We webcast the science colloquia series associated with the scientific staff recruitment. Many external as well as STScI scientists made use of this series. Talks were held almost daily and it was nearly impossible for individuals to attend every presentation. Scientific staff members and members of the Science Recruitment Committee relied on either live presentations or access to the archive when their schedules conflicted with attendance at the colloquium. DTI received extensive positive feedback for supporting this series.

NASA Administrator Sean O'Keefe's address to NASA and Contractors (split for DAT5K) - Instead of splitting from the DAT5K group, we took the feed from NASA TV and webcast internally.

Astrophysics of Life - May Symposium & Science Writers Workshop (split with DAT5K) - This was a highly successful production of the STScI May symposium. It represented the culmination of the experiment. The streaming ran smoothly, logistics were straightforward and we recognized that many speakers used our guidelines in preparing presentations. We were very pleased to see that in one year's time most speakers had migrated to digital presentations that work well for both live audiences (especially for the individuals at the back of the auditorium) and for webcast viewers.

Former Administrator Dan Goldin's Presentation at STScI - This webcast was a last minute emergency effort captured with only 3 minutes notification. The last minute implementation presented problems. The encoder, while running, was not accumulating the webcast. After the presentation we re-captured the talk from a video tape provided by OPO.

NASA Robotics Finals in Orlando, FL - (split for DAT5K) We participated in the webcast to close out the Robotics series. As a public interest note: Steven Spielberg is making a movie about the head of the NASA Video Streaming Group, Alan Federman, and his work with the troubled kids and involving them in the NASA Robotics project. Alan Alda plays Federman.