Office of Public Outreach
Monograph Series
Number 101

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SPACE TELESCOPE SCIENCE INSTITUTE
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The Office of Public Outreach (OPO) at the Space Telescope Science Institute (STScI) collaborated with the San Francisco Exploratorium, a cutting-edge science museum, to produce live, interactive webcasts twice daily during the 1997 Hubble Space Telescope Servicing Mission. Using a sophisticated multi-media center in the museum, "explainers" described the daily servicing mission activities to a museum and a Web audience. They also showed NASA videos of daily mission activities, conducted videoconferences and telephone interviews with scientists and engineers from STScI and other organizations, as well as provided slide shows and animation from an extensive STScI archive. Museum visitors interacted with the explainers and experts, asking questions that set the course of discussions. The Exploratorium and OPO share the common goal of using emerging technologies to allow the public to do more than just "download" information regarding science research. This technology enables the public to participate in the inquiry and discovery as well as experience authentic environments of scientific research. Based on the results of this experiment, the Exploratorium and the OPO will continue both collaboratively and separately to use webcast techniques to interact with the interested public regarding science and technology content.

Introduction

Interactive online multimedia are becoming increasingly accessible for a broad range of educational applications. In the informal science education community, multimedia facilities are used more often in stand-alone mode on the exhibit floor, e.g., as a kiosk, while online interactions are less common. Further, the effective translation of science research into a format palatable to the public is receiving increased attention and funding yet the tension between the scientific community and educators and/or the general public remains. Clearly, appropriate brokers who can mediate the complexities of science research to the public are a key element. This brokerage is a fundamental aspect of science centers (museums). Science centers have a key role within the community for conveying the latest advances in science and technology. Science centers also con-

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tribute significantly to the professional development of science, mathematics,

and technology literacy teachers in the U.S. In order to respond to cutting edge research developments, science centers necessarily desire to maintain excellent communication with active scientists and research institutions. Through science centers, the latest scientific and technical advancements can be conveyed to the public in an educational, yet exciting, engaging and understandable way.

Science centers such as the San Francisco Exploratorium have investigated the thesis that public space can be configured to enable the genuine experience of personal inquiry through interaction and discovery. [1,2] Creation of hands-on exhibits within a museum that allow for two-way interactions is a tried and true methodology for encouraging exploration. Alternatively, broadcast media, used to connect the public to scientific and technology events such as early coverage of space flights, interviews with NASA Space Shuttle and MIR crews, question and answer sessions with Mars Pathfinder scientists, etc., is highly effective and engaging but may lack in scientific depth. Programs intended to contain more educational content such as ``Live from Antarctica''[3] and as early as the Pioneer flyby have shown such broadcast events can be potent also. Our hypothesis for this paper is that a new combination of two-way exploratory interaction and broadcast techniques could be a powerful methodology for creating an enriched personal experience of scientific inquiry. Our contention is that creation of an environment on the museum exhibit floor that provides a connection to a remote live event, and mediated by knowledgeable brokers provides a new, innovative environment for informal science education.

As a first step, we developed a modest experiment which utilized multimedia, live television production techniques, and the Internet to test methodologies for creating an novel learning environment in which science museum visitors and World Wide Web users could experience first hand current events in science. The experiment was developed out of a collaboration between the San Francisco Exploratorium and the Hubble Space Telescope Science Institute (STScI) as one of a suite of experiments and activities aimed at bringing science and technology to an interested general audience in a timely and highly leveraged fashion.

The experiment, called *Looking Beyond Boundaries,* brought together multimedia resources and videoconferencing in a live broadcast on the Web together with interactions with a studio audience comprised of visitors to the Exploratorium. It included live audio and video broadcasting on the Internet at published, scheduled periods. The live studio audience also serves as surrogate participants for the remote ``virtual'' visitor, specifically through their active participation and communication with the science center staff and the contact with the scientist or engineer directly associated with the science event. The context of the broadcast was the NASA's shuttle Servicing Mission of the Hubble Space

Telescope (HST) in 1997, which afforded an opportunity for visitors to explore a variety of scientific and technical subjects with accessibility to experts from the mission.

Goals

Looking Beyond Boundaries was designed to address a number of specific objectives:

- to demonstrate that museums are effective brokers of science content and allow a wide audience to personally experience the process of scientific inquiry and develop a better understanding of the technology behind the science
- to experiment with new multimedia techniques using the Internet and to avoid simply using text and pictures (``books online'') to provide information on the subject matter
- to test affordable, accessible emerging technologies (as opposed to more expensive facilities such as MBONE and higher bandwidth custom networks used by the research community) to bring an event to the public
- to enable remote visitors to personally experience the nature of scientific inquiry and technological advances as they happen
- to evaluate live visitor response in participating in the live studio format
- to gain experience in multimedia, live productions for incorporation into future, more highly publicized events
- to understand best practices for researchers to use when interacting with a live, but remote audience
- to evaluate the method by which such interactions could be integrated into science center exhibits
- to understand how such methodologies might be integrated more formally into curricula

The intent of the experiment was to produce an in-depth, rarely seen, behind-the-scenes look at NASA's Hubble Space Telescope Servicing Mission

Context

The intent of the *Looking Beyond Boundaries* experiment was to produce an in-depth, rarely seen, behind-the-scenes look at NASA's Hubble Space Telescope (HST) Servicing Mission, which took place in February, 1997. The aim was to allow participants to experience the challenges, personalities, science and technologies which together made up this complex shuttle mission which would enable new, more advanced scientific investigations. The experiment was accomplished through a series of live, Internet audio and video "webcasts " from a production studio on the Exploratorium exhibit floor. The studio, a temporary structure built by the Exploratorium's Center for Media and Communication (CMC), offered museum visitors and Internet viewers an opportunity to encounter the servicing mission in greater detail than was presented through the news media coverage or any other venue including other Web sites.

Experimental Setup

Content

OPO and CMC collected a rich collection of images, sound files, video clips, animation, and developed Web pages to serve as multimedia content for the productions. These resources were stored on computer disk and on 3 programmable laser discs used as a digital library. Additional links were created to provide quick access to pertinent external Web sites such as the shuttle information at NASA's Johnson Space Flight Center. OPO staff also produced a mission update daily summarizing the Extravehicular activities (EVA) conducted by the shuttle crew overnight and the status of the science instruments and the telescope (only available through STScI).

Images included digitized color renditions of HST science observations of specific objects such as the Hubble Deep Field [4], star formation regions such as the Eagle Nebula [5], various planets and other interesting astronomical objects [6]. These were used to demonstrate the current scientific research conducted with HST and prospects for new investigations with the state of the art instruments being installed. Digitized images of the new instrumentation to be installed in HST included those of the Near Infrared Camera and Spectrograph (NICMOS), the Space Telescope Imaging Spectrograph (STIS), and the Solid State Recorder (SSR).

Digitized photographs of astronauts practicing installation of instruments and other key points in the training for the mission also were contained in the digital library. Technical animation available through the digital library demonstrated the capture of HST by the shuttle Discovery, and installation and removal of instruments by astronauts. A variety of video clips were included, such as the practice sessions in the Neutral Buoyancy Tank and dubbed segments to explain specific HST science results. Other animation illustrated representations of physical phenomena being probed through HST observations such as black holes in the center of galaxies, sublimation on the surface of planetary satellites and formation of quasars. Animations of full globe images of a number of the planets, assembled through mosaics of snapshots of those objects taken with HST were especially popular. Playbacks of video taken during the EVA were recorded, particularly useful considering that most EVA took place around midnight for the continental US. The live NASA TV was available through the Exploratorium's satellite down link. The live NASA TV included crew wakeup calls, instructions for upcoming activities and status reports on testing the telescope and instrument systems.

The above items were available to serve on call as illustrative tools for presentations by the Exploratorium staff and by the experts who were to be connected through video and teleconferencing facilities

Technology

The Exploratorium computers, which were used for the webcast, were Macintosh servers with at least 32 Mbyte of memory. One computer was used for the "Presenter", one was used

for the RealAudio encoding and another for production of graphics and textual information to be integrated into the webcast and one computer as the server for the webcast itself. The choice of computer was weighed by considering the ease of integration of audio and video into a real-time production environment. Networking is straightforward also.

The videodisc players were interfaced to a switcher so that the webcast presenters could select the appropriate graphics, animation and images for the context of the broadcast. Laminated cards displaying an index to the disc contents were available for quick, visual reference during the productions.

The video conferencing between OPO and the studio at Exploratorium was implemented through a Picture Tel© 1000 with a 6 channel bonded call connection via ISDN line. This video signal was available through a switch, as were the cameras that afforded views of the audience, the presenters, wide shots of the studio, and additional views of the museum exhibit floor. A miniature camera, the so-called "lipstick" camera, was used for perspective shots of the HST model.

Experiment Timeline and Production

Throughout the course of the 10-day HST Servicing Mission, the *Looking Beyond Boundaries* ``webcasts'' and demonstrations were incorporated by the Exploratorium in a series of scheduled twice daily interactions between the in-house science educators, the studio audience and the remotely connected guests (scientists and engineers). These presentations integrated the live NASA TV broadcast, all the digital library facilities and the human experts together. The Web materials and playbacks of prior sessions were available via the Internet during the remainder of the time.

The studio was designed with two discreet sets of functions divided between the Producer and the Presenters. During each scheduled hour long session, the Exploratorium staff members serving as the webcast video Presenters were primarily responsible for controlling the content of the program. The Producer was responsible for crafting a sensible webcast by switching between the available sources of input. The content was integrated from any of several video cameras in the studio, any web page, the NASA TV broadcast or the video from the online STScI expert, or audio from other exerts participating in the event. The remote viewer would then see the selected video and any other materials that had been chosen. During a webcast, the Presenters also served as the studio audience hosts and science content mediators by selecting the specific digital images, animation, NASA TV broadcast or playback or the video from the online expert for display on one of three large monitors in the studio.. Therefore, the Presenters could improvise, experiment, follow up on audience questions and react to surprise developments quickly. The Producer then worked to allow the remote viewers to share in the event. The division of labor between the Producer and Presenters was important so as to pre-

serve the real time nature of the broadcast, but shared in an intelligent way. The webcast also provided a vehicle for the human expert to become a hyper-linked live Web resource to be integrated into the production. The audio from the session was continuously available through Real Audio on the Web.

Webcast Scenario

During each broadcast, the Exploratorium staff gave a short introduction to the studio setup, and discussed briefly how HST works and the purpose of the Servicing Mission. In each case, a live audience was present, mostly comprised of chance science museum visitors. At least one expert from the science community participated in each session. Before each webcast, OPO provided to CMC *via* email or telephone the name and field of expertise of the live participants. In each hour, the broadcasters keyed their discussions to the expert available; to bring the live participants along a specific science or technical thread germane to the expertise of the online scientist or engineer. After interaction between the broadcasters and the expert, the live audience was engaged in discussion and questions. They were free to follow any subject they chose and continue dialogs with the broadcaster and the expert. The Exploratorium staff would access particular animation, images, video files or web sites to illustrate a point or to aid in the discussion. Most remote expert participants viewed the Web broadcast while interacting with the Exploratorium staff and the audience.

By viewing the Web link, the expert could direct the viewers to notice specific features in the images, animation and graphics being displayed on the monitors in the studio. This took some practice in order to get adequate synchrony between all the components and personnel. In some cases, viewing the Web became a distraction for the remote expert participant due to the

time-delayed feedback. However, usually the studio audience did not react negatively in response to the time delays between components and children participants were the most adaptable to the studio environment. Web visitors were usually experienced and adapted to the webcast accordingly. For example audio reception was always good, so much so that some Web visitors reported hearing some unwanted audio feedback in the museum experienced in one of the earlier sessions. Video delays were reported but Web visitors always remarked that though they were disappointed at the delay, they expected it due to their access bandwidth limitations. In the future, we intend to experiment with cutting edge video products such as RealVideo©, which was not yet released during the experiment. As in any live production, staff supporting the event experienced periods of intense activity and periodically were required to ``instantly'' rectify technical difficulties.

The Exploratorium also conducted offline sessions and offered hands-on activities for children, families and other visitors that related to the Servicing Mission, such as building simple spectrographs, introduction to the Internet and other subjects. Since the studio was located in the midst of the Exploratorium exhibit area, museum visitors could investigate other science topics before or after their webcast participation. Exploratorium staff continued their close interaction with a network of classrooms and teachers established through the COVIS, Science Learning Network and Science Information Infrastructure projects funded by NASA and NSF by providing updates and online activities.

Evaluation

Methods and Instruments

OPO staff led the development of the evaluation methods for the experiment. The other experimenters concentrated on deploying the technologies and collating content so that the evaluation plan lagged the experiment planning. Nevertheless, the *Looking Beyond Boundaries* experiment was documented through video taping at both participating sites, and in written reports. A survey for the Exploratorium studio audience and for the Web visitors was developed. The survey form was circulated in printed form at the museum and linked from the *Looking Beyond Boundaries* Web pages. CMC and OPO collected additional anecdotal data, in the form of commentary and observations through email and phone calls. The OPO evaluator interviewed key experiment participants individually at both institutions to collate insights regarding both process and the products of the project. Collective debriefing sessions were held in person or by teleconference to compile common themes in the evaluation. The evaluator also interviewed each individual STScI expert who participated.

The instruments of evaluation, i.e., individual interviews and collective discussions have been found by OPO and CMC to be highly productive in other venues, and have been demonstrated to provide far more in depth information in a timely fashion com-

pared to written or electronic forms, particularly for online resource use. Standard questions were posed to each person interviewed, but the format allowed a freer and more complete discussion than more tersely constructed form-based instruments. Other instruments such as Web hits and other related metrics were compiled as well.

The evaluation of the project reflected the experiment structure focussing on the planning, execution and the review phase. The next section reflects this structure.

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Results

Overall Effectiveness

The experiment was specifically designed to be a low-key, modestly advertised event in order to concentrate on deploying the technology and studying the webcast studio methodology. Surprisingly, the *Looking Beyond Boundaries* Web-based audience filled to capacity both the Exploratorium and Institute T-1 network lines over the 1997 President's Day weekend. Exploratorium staff noted that a holiday weekend with very good weather in San Francisco usually engenders lower public interest both in visitor turn out and in Web usage. This particular weekend was an exception, primarily due to the advertisement of the *Looking Beyond Boundaries* event.

The data collected is summarized as follows:

- Approximately 400 persons participated in the live studio events.
- The webcast site itself received more than 230,000 Web hits, averaging approximately 26,000 per day over the experiment's nine-day duration. Other related links received equivalent accesses.
- Users from 40,000 unique hosts accessed the Web site, demonstrating a widespread audience and interest
- Web users were distributed worldwide. The highest percentage of accesses beyond the United States came from Canada, Sweden, the United Kingdom, Australia, Germany and Japan.
- 95% of the respondent Web viewers stated that the webcast format was an effective way to provide the public with current scientific and technological information.
- 85% valued that the science and technical Web information was more in-depth than anything presented through other media, most notably the news. Some users, both abroad and in the continental US reported that in locations where normal TV reception is poor and news coverage of the Servicing Mission was sparse, the experiment was especially appreciated and became a fundamental source of information.
- 95% of the users reported they would visit the STScI Web site again.
- 78% stated that the science was explained well
- 95% of the respondents stated that the webcast was an effective way

to communicate science information, and a similar percentage stated that future broadcasts should be integrated into the same format

- 74% of the viewers tuned in to a webcast more than once and 31% accessed the webcast more than 11 times (the webcasts were conducted twice daily for 11 days)
- The experiment's Web page was daily in the top 4 pages of servicing mission Web pages offered from STScI, which also included a "Mission Update" page.

OPO and CMC staff noticed that attendees posed fairly sophisticated questions, demonstrating prior knowledge of the subject matter and asked follow-up questions during the broadcasts, engaging in thoughtful dialog with the Presenters. Many participants came prepared for the event, demonstrating keen interest in the science content, HST, and the Servicing Mission. It was logistically impossible to conduct pre- and post- testing of participants, particularly Web viewers, and therefore the actual improvement in the public's understanding of science and technology could not be quantitatively measured. However, considering their testimonials, participants appeared to have increased their understanding of some facet of the content provided.

Collaboration Success

Exploratorium reported a great benefit in collaborating directly with a scientific research institution such as STScI, offering specific expertise allowing the museum staff in turn to address current late breaking science events in response to pubic interest. In addition, OPO was able to provide many relevant online resources that were key to the experiment. The materials and direct interaction with the experts at STScI allowed the museum personnel to develop their own understanding of HST, its instrumentation, and the HST science program so they in turn could mediate the content to a large audience.

OPO benefited greatly from the collaboration by participating in a clear demonstration of the brokerage power of science centers. While the experiment demanded intensive attention from STScI staff, the expertise was accessible by a very wide audience which would not have been reached effectively through more traditional methods (lectures, phone calls, one-on-one interactions).

Staff from both institutions reported the experiment provided better clarity regarding the types of collaborations that would be feasible in the future.

Planning Phase Evaluation

Goals and timeline: The project participants all agreed that the Co-investigators (C. Christian and R. Semper) communicated the goals and expectations of the project to each other and to all participants. All stated that the time period for acquisition and implementation of the appropriate technology for the live link was underestimated, leading to a compressed schedule near the time of the Servicing Mission. One point of contact at each Institution was designated to simplify communication between

participants. This important "one point of contact" lesson is consistent with that derived from both the ``Live from the Stratosphere'' and ``Live from Hubble'' projects that the Exploratorium and STScI supported in the past.

Technical aspects: Most of the problems encountered revolved around deployment of the commercially supplied technology that was implemented to provide the interaction between CMC and OPO during the webcasts. Other components such as the video feed to the Internet, the audio server, the Web servers, the laser disc digital library facility and the network connections were reliable. Miscommunication and unfamiliarity with the video link technology lead to delays. CMC was mystified by the complex procurement procedures that OPO must comply with, being a recipient of federal funding. The procurement lead to delays although STScI staff responded valiantly to the challenge. The short funding cycle and long procurement times also prohibited extensive pre-testing and rehearsals. Both sites communicated that such exercises would have been highly valuable.

The availability of multimedia resources in a large farm that can be user selected across the Internet as well as incorporated into real-time events is an important outcome.

Promotion: Both institutions found that coordinated promotion and press releases would have increased clientele for the project. After the experiment Web page was linked from external NASA pages, Web participation increased. Both institutions concurred that more frequent and comprehensive communication and planning would have improved the experimental conditions, but it is recognized that all the staff was severely over committed which often prohibited such optimal interactions.

Execution Phase Evaluation

Constant communication between OPO and CMC immediately before and during the webcasts was essential. The staff at both sites appreciated gaining experience in pushing into unknown territory in a project that was typified by good spirits and a sense of experimentation. CMC staff were surprised and pleased that the project management at OPO was flexible, organized and detail oriented.

Technical aspects: OPO staff reported that earlier technical specifications and procurement would have been helpful so that deeper experience with equipment could have been attained. A more robust testing schedule would have been beneficial. The primary technical glitches at the studio were the lack of RealAudio stream on the first day, and sporadic audio feedback howls early in the program. The feedback is difficult to control for live internet communication, especially from a noisy environment with multiple microphones and a public address system.

Resources: A critical aspect of *Looking Beyond Boundaries* was the ability of OPO to provide two guests each day. This was no small effort and certainly was the centerpiece of the webcast series. All guests were clearly interested in the experiment, and although some were less comfortable on camera than others, the group of experts was perceived as lively, friendly, ap-

proachable and adaptable to the labyrinthine technical set up.

OPO reported that the third party consultant tasked to work on the PictureTel system was not cooperative, resulting in many delays. The ideal situation is to work with PictureTel directly. The OPO space used for the video conferencing was not ideal for the experiment, but that environment was in the process of redesign, partly to accommodate such events.

It was remarked by staff at both sites that a recording of day-to-day events was beneficial for changing and improving the productions and serve as a valuable documentation source.

Production: It was agreed by both sites that the overall format of the webcasts worked well. In future events, a back channel of communication would be valuable for off-screen staff to improve adjustment of cameras, lighting, audio, appearance of the webcast, and to coordinate logistics. Most guests would have benefited by having the ability to view the audience, perhaps through a back channel. An introduction to the studio and the set before each session through hand-held camera feeds would have been helpful for the guests.

The audience and remote viewers appeared to respond best to guests that dressed in "business casual" rather than suits and ties. OPO and CMC noted that casual dress appeared to set a more cooperative, approachable mood and set the audience at ease, without detracting at all from the informal learning environment.

Evaluation plan: The evaluation of the events by the studio audience was a bit cumbersome and required participants to move to a separate location to complete the forms. This situation should be improved for future events. The online feedback buttons were used regularly by webcast viewers and the response was overwhelmingly positive. This is perhaps a bit unexpected since experience at OPO and CMC has shown that web users are more likely to provide negative commentary rather than expressing praise or positive enthusiasm. The daily video documentation was valuable for accessing audience reaction after the broadcast was over, particularly because *in situ* evaluation was difficult.

Summary and Lessons Learned

The experiment resulted in achievement of the major goals and laid the groundwork for productive collaborations in the future. *Looking Beyond Boundaries* can be described as a successful implementation of a novel learning environment. Based on the input from staff and from the data from the studio and Web audiences, the program was well received and was referred to as an interesting way to learn about major scientific and technological events. Areas of improvement in the planning stage such as early procurement of equipment and a schedule of testing would be beneficial. Solving technological issues early will enhance broadcasts and improve the ability of the staff, the guests and the audiences to interact freely and spontaneously. The availability of

multimedia resources in a large farm that can be user selected across the Internet as well as incorporated into real-time events is an important outcome. It is recognized that stronger, more robust and more timely evaluation planning and execution can be designed

Future Directions

Based on this experiment, the Exploratorium and the OPO at STScI will continue both collaboratively and through separate efforts to use webcast techniques to interact with the interested public regarding science and technology content. *Looking Beyond Boundaries* provided a springboard for creation of more permanent broadcast facilities at Exploratorium, and future endeavors will include webcasts that integrate live video from a variety of situations and events with ancillary information and multimedia resources. It is of keen interest on the part of OPO staff to incorporate webcasting in the suite of interactive tools used to convey the science research undertaken with HST. Exploratorium and OPO share the common goal to use emerging technologies to allow the public to not just "download" information regarding science research, but to use the technology to participate in the inquiry and discovery as well as experience authentic environments of scientific research.

Acknowledgements

This work is supported by contract NAS5-26555 to the Association of Universities for Research in Astronomy, Inc. for the operation of the Hubble Space Telescope. Many talented and generous individuals contributed to the success of this experiment and we acknowledge their valued participation. We wish to note in particular Marian Iannuzzi for her tireless support of the program.

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