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ABSTRACT

Research has been conducted which develops case studies on how to engage scientists in partnerships with teachers. Studies have focused on the Internet and the World Wide Web as potential conduits of research results to the classsroom, particularly if scientists and teachers were involved in joint creation of Internet-based curriculum and lesson plan development. This document outlines that research, describing both theoretical and actual establishment of a teacher-scientist partnership. It discusses the collaboration strategies of a fourth-grade teacher from Oakland, California, and a National Aeronautics and Space Administration satellite operations scientist who worked together to create an Internet tool which taught the concept of movement of light photons in satellite dataflow. The relationship can be characterized as a mutual cognitive apprenticeship, in which the scientist begins as content expert only and the teacher begins as pedagogical expert only and each learns from the other. Transcripts of comments made by the two collaborators to an interviewer are included. Textual and visual representations of satellite dataflow are appended. (Contains 18 references.) (BEW)

Science-On Line: Partnership Approach for the Creation of Internet-based Classroom Resources[1]

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Abstract

Our investigation is developing case studies which investigate how to engage scientists in partnerships with teachers and other educators for the purpose of adapting research results to enhance classroom science curricula. Owing to the pervasive use of networking technologies - such as the Internet and the World Wide Web - in the scientific workplace, our study focuses on these tools as potential conduits of research results to the classroom. This study is part of a research program that is identifying effective strategies used by teachers in the contextually-relevant process of Internet-based lesson-plan development (Battle and Hawkins 1996). Our strategy for evaluating our partnership approach engaged the participation of personnel from scientific research institutions, centers of informal science learning, and schools. The goal of our broader research program is to develop a viable model to support teachers in the adaptation of science research for their classrooms, taking advantage of a more technologically-driven, research-based model of teaching and learning. We address the hypothesis that the transition of scientific data and research result from the workplace to the classroom can be facilitated by the joint creation of curriculum materials by teams of cognitive experts, subject-matter experts, and teachers. In this paper, we study the partnership between a teacher and a scientist who worked together to create an Internet-based classroom resource. An analysis of the partnership between the teacher and the scientist allowed us to identify modified elements of cognitive or traditional apprenticeship relationships. We define ***mutual cognitive apprenticeship***, a variant of the traditional apprenticeship relationship, in which the teacher and the scientist played both bonafide novice and expert roles early in their relationship. This study, along with the work of Battle and Hawkins (1996), serves as an example of a methodology to provide the scientific community with a viable mechanism for sharing research results with a broader audience in educationally-relevant ways.

1. Objectives and Introduction

The study presented in this paper is anchored in a theoretical framework that focuses on two issues: (a) expert/novice roles during the development of a multi-media classroom resource requiring both pedagogical and scientific expertise, and (b) collaboration strategies used to implement the transition of highly scientific and technical information to formats and representations suitable for non-expert consumption using the Internet and World Wide Web. Two projects led by UC Berkeley's Center for EUV Astrophysics: "Science On-Line" and "NASA Satellite Class for Teachers" set the stage for the research presented here. Both projects are founded on a model of collaboration, which typically includes personnel from research institutions, centers of informal and formal science teaching, schools of education, and K-12 schools. In this paper we describe the collaboration of a team composed of a teacher and a scientist as they worked to adapt a demonstration of the dataflow of a NASA satellite using the HyperText Markup Language (HTML) protocol of the World Wide Web - a relatively new authoring and representation medium for K-12 curriculum materials.

1.1. Outline of the Paper

This paper is structured as follows. First, we discuss the theoretical framework, then we describe the establishment of the teacher/scientist partnership. We continue with a Data and Methods section followed by the Results section, where we provide a preliminary analysis of the videotaped and transcribed interviews between the authors and the teacher/scientist team. We conclude with a summary of the results and a discussion of their educational significance. An appendix includes details of the dataflow demonstration only as necessary for understanding the content of this paper. The on-line lesson plan based on the demonstration can be found at the URL:

http://www.cea.berkeley.edu/Education/dataflow

2. Theoretical Framework

Current educational research has placed increased emphasis on "activities" or "coherent human actions" (Sherin, diSessa, & Hammer 1993) as a central target of educational design that responds to the philosophy of both materially- and socially-situated learning (Brown, Collins & Duguid 1989). Examples of "activities" include the frameworks of traditional apprenticeship (Lave and Wenger 1991), cognitive apprenticeship (Collins, Brown & Newman 1987), and Community of Learners (Brown 1992; Brown & Campione 1994; Brown & Palinscar 1994). The teacher/scientist partnership analyzed in this paper responds to the basic premises of cognitive apprenticeship as outlined by Collins, Brown and Newman (1989). Namely, the teacher/scientist team worked together for the specific purpose of designing a scientifically- and pedagogically-rich Internet resource, whereby they would teach each other the processes that experts use to handle a complex task.

In this case, the task involved the Internet-based representation of a fundamental, yet technically difficult, satellite operations function for use within classroom curricula. As part of this complex task, the teacher/scientist team addressed a certain amount of both conceptual and factual knowledge (e.g., domain knowledge, as well as heuristic, control, and learning strategies). However, these types of knowledge were implemented and situated in the context of a specific application. We study the teacher/scientist expert/novice roles in this context. The traditional and cognitive models of apprenticeship contain common elements that are sequenced to allow a gradual transfer of expertise from expert to novice and, thus, increased independence by the apprentice. These common elements can be summarized as "modeling," "coaching (through scaffolding and other support techniques)," and "fading" (Lave and Wenger 1991; Collins Brown and Newman 1989). In this sequence of activities, the novice observes the expert executing or modeling a given task or technique which may involve various interconnected sub-tasks. The expert and novice then switch roles, allowing the novice to practice the task demonstrated by the expert. This step requires a well-structured support system ("coaching") which typically includes scaffolding in the form of cues, hints, and the partial provision (by the master) of needed domain or heuristic knowledge (to the apprentice). As the level of expertise of the apprentice increases, the expert fades, so that the level of independence of the apprentice or novice increases. One key difference between traditional and cognitive apprenticeship (the former pertaining primarily to learning-through-guided-experience of physical, vis-a-vis cognitive and metacognitive, skills) is that applying apprenticeship methods to largely cognitive skills requires externalization of processes that are usually carried out internally (Collins, Brown and Newman 1989). The use of the computer enabled our teacher/scientist team to, at least in part, externalize their thinking through the easily updated environment of the World Wide Web.

A second theoretical focus of this study is in the context of collaboration strategies used to implement the transition of highly scientific and technical information to formats and representations suitable for non-expert consumption using the Internet and World Wide Web. The work of Larkin and Simon (1987), Hildebrand (1989), Kaput (1987); and more recently Sherin, diSessa & Hammer (1993) and Hall and Stevens (in press), support the belief that external cognitive representations play a critical role in people's ability to learn and to generally engage in cognitive, metacognitive, and reflective exercises. Sherin, diSessa & Hammer (1993) argue that an effective way of supporting physics inquiry is to shift the context of what is being taught and learned to activities that are familiar to students, yet still engage them in a form of physics inquiry. These authors advocate the activity structure of "design" as a viable way of conveying to students the nature of an abstract task, owing to children's early familiarity with the activity of making, modifying, fixing, and revising physical things and other representations such as drawings or pictures. The purpose of the teacher/scientist collaboration was to jointly create a design for a multi-media representation of the "Satellite Dataflow" demonstration. The design activity provided the teacher/scientist team with a familiar way to articulate and externalize their respective expertise.

In this study, the authoring medium for the teachers/scientist team's collaborative work was the Internet and the World Wide Web. Major emphasis has been given to more relevant curriculum and models of learning that more closely reflect workplace learning (Becker, 1972; Lave and Wenger, 1991; Collins, Brown, and Newman, 1989). Similarly, Park and Hannafin (1993) suggest that students and teachers benefit by learning how to use technological tools found in scientific, academic, and business workplaces. A specific scientific discipline has specialized and characteristic forms of discourse, including not only jargon, but ways in which research is carried out via the formulation of hypotheses and conjectures, the interplay between theory and observations, and the way in which new results are related to accepted knowledge (Schoenfeld 1985, 1987). Thus, the creation of effective curriculum that reflects the practices of the workplace can benefit from the integral participation of subject-matter experts. Use of technology in the classroom can foster an environment that more closely reflects the processes scientists use in doing research (Linn, diSessa, Pea & Songer, 1994). For instance, scientists rely on technological tools to model, analyze, and ultimately store data. Linn, diSessa, Pea & Songer (1994) suggest that technological tools be introduced to students from the earliest years because of their ability to facilitate scientific modeling, scientific collaborations, and electronic communications in the classroom. The introduction of technical innovations into the classroom has the potential to produce a dramatic redefinition of traditional teacher-student instruction (Park and Hannafin, 1993). These authors suggest that multimedia lends itself to a powerful representations of information because it allows for the "...combination of visual, verbal, and tactile stimuli..." However, they believe that use of multimedia may have difficulties for both instructional designers and learners, unless the emphasis is on conceptual organization and depth, not merely information retrieval. The collaboration of teacher and scientist, with their available expertise in both science and pedagogy, would potentially result in a more robust representation of the "Satellite Dataflow" demonstration.

3. Establishment of the Partnership

The teacher/scientist team was composed of a 4th grade teacher from the Oakland Unified School District and a satellite operations scientist from UC Berkeley's Center for Extreme Ultraviolet Astrophysics, which operates the Extreme Ultraviolet Explorer NASA satellite. The scientist had developed, independently, a demonstration of the flow of data (light photons) from a distant star or other source of extreme ultraviolet radiation to a scientist at the UC Berkeley Center for EUV Astrophysics. The purpose of the demonstration is to illustrate, through a kinetic activity involving human participants, the light path and communications path involving a star, the EUVE and other NASA and commercial satellites, various ground stations on the Earth, and a scientist at UC Berkeley who is interested in analyzing the data from the star. The scientist had created the demonstration in response to the frustration he felt whenever he had to explain the EUVE satellite dataflow to technical personnel. During several viewgraph-style presentations, the scientist had attempted to demonstrate the concept of the satellite's dataflow (a key mission operations concept in space science) to technical audiences via a paper diagram. The failure to elicit robust understanding of this key concept in the technical audiences motivated the scientist to create the kinetic demonstration. During one of the videotaped interviews, the scientist expressed his motivation for developing the demonstration:

> "It was very, very confusing and eventually we abandoned the diagram that I had. Well, the whole reason that I had done this demonstration was because of this slide, viewgraph, that someone had produced, that was so confusing no one could understand it, and every time I presented it to someone you could see the blank stares in people's faces. So, I developed [the demonstration] as a way of communicating what was going on, uh, in a dynamic way..."

The scientist had empirical evidence that the diagram (Figure 1) was an inadequate representation of a fundamental space science concept - a satellite's dataflow. Even technically-literate audiences (who would be expected to possess domain schemas as a consequence of several years of experience working on NASA satellite missions) had been unable to internalize an appropriate conceptual model. The primary constraint, in the scientist's mind, was the diagram's inability to convey the dynamic nature of the dataflow concept. The scientist eventually began to use the kinetic demonstration with pre-college students as part of Lawrence Hall of Science summer camp and other community outreach activities.

Subsequently, the scientist began to work with the teacher as part of an Education Department (UC Berkeley Extension) semester-long class for teachers taught and evaluated by the authors. The class of 20 teachers met at the Center for EUV Astrophysics 3 hours per week during 17 weeks, and supported partnerships between scientists and teachers to develop Internet-based lesson plans for the classroom that tapped NASA resources. The "Satellite Dataflow" demonstration was performed by class participants, and our particular scientist/teacher team decided to design a lesson plan based on the demonstration which would utilize the capabilities of the Internet and World Wide Web to provide a multi-media representation. The team worked together for 30 hours when the class was in session and continued their collaboration during the following summer for an additional 50-80 hours. Details of the Satellite Dataflow Demonstration are given in the Appendix.

4. Data and Methods

This qualitative study involved the analysis of team practices that emerged from the interaction of a teacher and a scientist as they collaborated to adapt a demonstration of the dataflow of a NASA satellite using HTML, to provide multi-media access of this demonstration by the K-12 teacher community through the World Wide Web. The authors examined expert/novice roles as the team developed the "Satellite Dataflow" multi-media resource, focusing on the division of labor and emergent collaboration strategies used to implement the transition of highly scientific and technical information to formats and representations appropriate for the classroom. Two 2.5 hour interviews with the members of the team, individually and together, were videotaped and converted into transcripts for analysis by the authors. For the purpose of protecting the team's identity, we have called the scientist "Paul" and the teacher "Marilynn." Their genders are preserved, however.

5. Results

One of this study's objectives was to bring scientists and teachers into closer working relationships in the context of developing a multi-media classroom resource. The partnership between the teacher and the scientist described in this paper presents modified elements of cognitive or traditional apprenticeship relationships. We define ***mutual cognitive apprenticeship***, a variant of the traditional apprenticeship relationship, in which the teacher and the scientist played both bonafide novice and expert roles early in their relationship, i.e., the teacher has expertise in pedagogy, while the scientist has expertise in the given science domain; however, the team members also take on novice roles in the relationship since the scientist typically lacks knowledge of classroom teaching techniques and the teacher's scientific expertise, in most cases, lags significantly behind that of the scientist. The idea of a dynamic/tactile representation of the "Satellite Dataflow" concept emerged from the scientist who, as the science expert, has a complex and conceptually-robust understanding of how a satellite's telemetry (relay) system works. The idea of making an engaging, conceptually-focused, lesson plan based on the demonstration emerges from the teacher who, as the education expert, has a robust understanding of how to best present new concepts to students. The following transcript excerpts between the teacher (Marilynn) and scientist (Paul) give examples of mutual recognition of their expertise:

The teacher (Marilynn) reflected on her role as science novice:

> "There were a couple of times, certainly. There were many times when I had no idea what was going on scientifically then I certainly relied on Paul' work..."

The following team dialogue highlights Paul's and Marilynn's respective expertise when asked how the idea for making the existing "Satellite Dataflow" demonstration into a World Wide Web lesson plan arose, and how they divided their work:

> Paul: That [the "Satellite Dataflow" demonstration he had created] was really only a piece of it. That was really more, uh...
>
> Marilynn: A procedure part.
>
> Paul: Yes, it was the procedure. Step by step what you do... Uh, but Marilynn provided the top level... Here is the lesson plan; Here's overall what it does; Here's the purpose;. Here's...
>
> Marilynn: The objectives.

> Paul: Here's what you need, the objectives of it. And, sort of linking all the other material besides 'here's just how to do it.'

The following team dialogue affirms Marilynn's role as pedagogy expert:

> Marilynn: Yeah, we collaborated fairly much on the final look of it. Well, I mean, I probably imposed my views on the look of it - pretty much.
>
> Paul: A lot of it....the lesson stuff was Marilynn's area.
>
> Marilynn: But the real scientific stuff, it was... Paul, you know.

As their collaboration progressed, the ***mutual cognitive apprenticeship*** character of our teacher/ scientist team provided a natural environment for the alternation of expert and novice roles as the team shared the task of solving complex issues of science concept representation, effective use of multi-media tools, pedagogy, and organization of the lesson plan featuring the "Satellite Dataflow" demonstration. Both teacher and scientist were able to model expert behavior in their respective domains from the outset, and this feature provides a key difference between "mutual cognitive apprenticeship" and the more traditional models, i.e., the teacher and scientist worked from the beginning in a collegial atmosphere of mutual respect for each other's expertise. Traditional apprenticeship relationships, such as those between graduate students and their advisors, tend to maintain a hierarchical structure even after many years beyond the time of doctoral graduation when, in many cases, the former student has achieved a level of expertise that equals that of the former advisor. In several instances the team members reflected on this issue. When Marilynn was asked whether she engaged the scientist in pedagogical discussions:

> Marilynn: Oh yes! Oh yeah - sure.
>
> Paul: That's my opinion on things, and...
>
> Marilynn: Of course, why not? I've been working with him [and] he's a colleague, and I want to know his opinion, and his name is going to be on it [the World Wide Web lesson plan].

And when Paul was asked whether he engaged the teacher in technical discussions:

> Paul: Like the front page, and how...
>
> Marilynn: How best to use... the graphics that [were] used.
>
> Paul: Oh, particularly the graphics...
>
> Marilynn: You know... those little graphics that I got.

> Paul: Yeah.
>
> Marilynn: How to unify it.

The team also reflected on what they had learned from each other:

> Marilynn: I know a lot more than I did. I definitely do. Yeah, about the actual workings [of] satellites, and where they go, and who's running them, and how the government [NASA] run[s] them... It was like - WHAT?!? You're using domestic communications satellites? I was amazed - totally amazed. I had no idea that NASA would use - well, rent [commercial satellite] time and just use it. I learned a lot more, too - the whole scientific aspect of it. Doppler shifts... things I would never have thought of.
>
> Paul: Did I learn anything from [Marilynn]?...oh sure! A lot of - I'm trying to think of something specific. More along the lines of, Marilynn would say, you know - "Kids aren't going to be interested in this" or, "You've got to present it this way," or that sort of thing. A lot of how to present things - how to keep people's interest. Can't be long, can't be boring, can't be this way, you've got to snap it up here. So - you know, [Marilynn] would make a lot of comments like that to keep peoples' interest. And to, uh - and making it into a lesson, making it into something that - I don't know. How to organize it. The top level organization that [Marilynn] did was, I never would have thought of that. She said - "Here's the purpose, here's what you're going to do, here's the materials you need, here's how much time it's going to take." Uh - giving people a teacher's...a teacher's perspective - I would not have had that at all.
>
> Marilynn: So scientists can learn from teachers too?
>
> Paul: Oh yeah, sure. Yeah, teaching, teaching people is a lot different than just presenting the science information.

As the team's level of comfort in each others' area of expertise grew and the task began to focus and solidify, the team resorted to using the World Wide Web as a remote shared work-space, by which the teacher and the scientist were able to implement "abstracted replay" techniques (Collins and Brown 1988). These techniques encouraged self-monitoring and self-correcting strategies as the team members critiqued and revised each others' work within their own area of expertise. This transition to more independent work and revision cycles (fading) naturally evolved as a consequence of the team's increased expertise and in-depth understanding of the task. This progression was apparent as the team discussed how they could continue their collaboration to improve the on-line "Satellite Dataflow" lesson plan. The World Wide Web representation of the classroom resource was of particular interest to teacher/scientist team. The teacher/scientist team explored various types of multi-media representations during the development of their "Satellite Dataflow" demonstration lesson plan: including static images, imagemaps, and a movie. In the interview excerpt below, where the team discusses the need for another video, both scientist and teacher engage collaboratively in both technical and pedagogical issues.

> Marilynn: It would be great to have a better video.
>
> Paul: Doing something like that videotaping, but maybe on the patio here or something, which is more of a confined space.
>
> Marilynn: Yeah, that'd be great.
>
> Paul: Or - or doing it on the playground...
>
> Marilynn: Back to my class.
>
> Paul:...where there is a circle. Remember that circle?
>
> Marilynn: Yeah, there is a circle along the asphalt.
>
> Paul: We could have tried that.

The teacher/scientist team created a seemingly more effective and robust representation of an existing "Satellite Dataflow" demonstration in the form of a World Wide Web lesson plan for teachers. The on-line resource is intended to facilitate access to scientific and technical space science information by other teachers with access to the Internet. Based on the team's self-stated reaction to their finished product, we argue that the resulting resource possesses several improved classroom-relevant features over the original demonstration (for example, compare the original diagram of the dataflow used by the scientist, Figure 1, with the modified version produced by the teacher, Figure 2). Further insight into the efficacy of the lesson plan in a variety of classroom conditions, however, is beyond the scope of this study.

Our preliminary findings indicate that the partnership approach between teacher and scientist resulted in a sustained collaboration which has a strong potential of continuing. Both team members offered their personal insight and recommendations based on their experience:

> Marilynn: I would never have done it without the collaboration of [a] scientist. Without Paul... I would never have done it - and it would never have gotten out. Certainly not in the format that it is that's really, I think quite useful. So, it's, I mean, collaboration is an important thing. It wouldn't have happened without it.
>
> Paul: And I guess a very important part of it is to say that it's okay to take a portion of work time and be able to do this.
>
> Marilynn: Yes - that's exactly what I'm saying. Yes, exactly! Without the time he was allowed, I mean, if he had had to do it on his own time you know, I don't know if it would have happened, right? So - It might not have happened.
>
> Paul: Right. It might not have happened. I'm very busy outside of work, too - yes.

Marilynn: Yeah, so that's an important thing.
Paul: Right.

Marilynn: But that's what I was saying about scientists being, you know, knowing, needing to know that the kids are the next scientists and the next, you know, supporters of science.

Paul: And it turns out that it doesn't affect the deadlines between - you know - work deadlines outside of this. You can take 10%, you can take a bit of time here and there to work on this.

Marilynn: Maybe we'll work on another one.

Paul: There are always ideas... Over the coming year - that's what I'd like to do.

Marilynn: Alright good. Another one coming. And I'll learn more UNIX - so that I won't have to rely on you so much for that. It was hard. Good. It was fun too.

6. Conclusions and Educational Significance

This project is enabling us to develop a coherent team approach for facilitating the effective access and use of scientific data and research practices by the K-12 community. This methodology provides teachers with science curriculum that engages their students in research-based classroom activities that take advantage of a technologically-rich environment. One of this study's objectives was to bring scientists and teachers into closer working relationships in the context of developing a multi-media classroom resource. The partnership between the teacher and the scientist described in this paper presents modified elements of cognitive or traditional apprenticeship relationships. We define ***mutual cognitive apprenticeship***, a variant of the traditional apprenticeship relationship, in which the teacher and the scientist played both bonafide novice and expert roles early in their relationship. This study, along with the work of Battle and Hawkins (1996), serves as an example of a methodology to provide the scientific community with a viable mechanism for sharing research results with a broader audience in educationally-relevant ways.

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Appendix

Details of the Dataflow Demonstration

http://www.cea.berkeley.edu/Education/dataflow

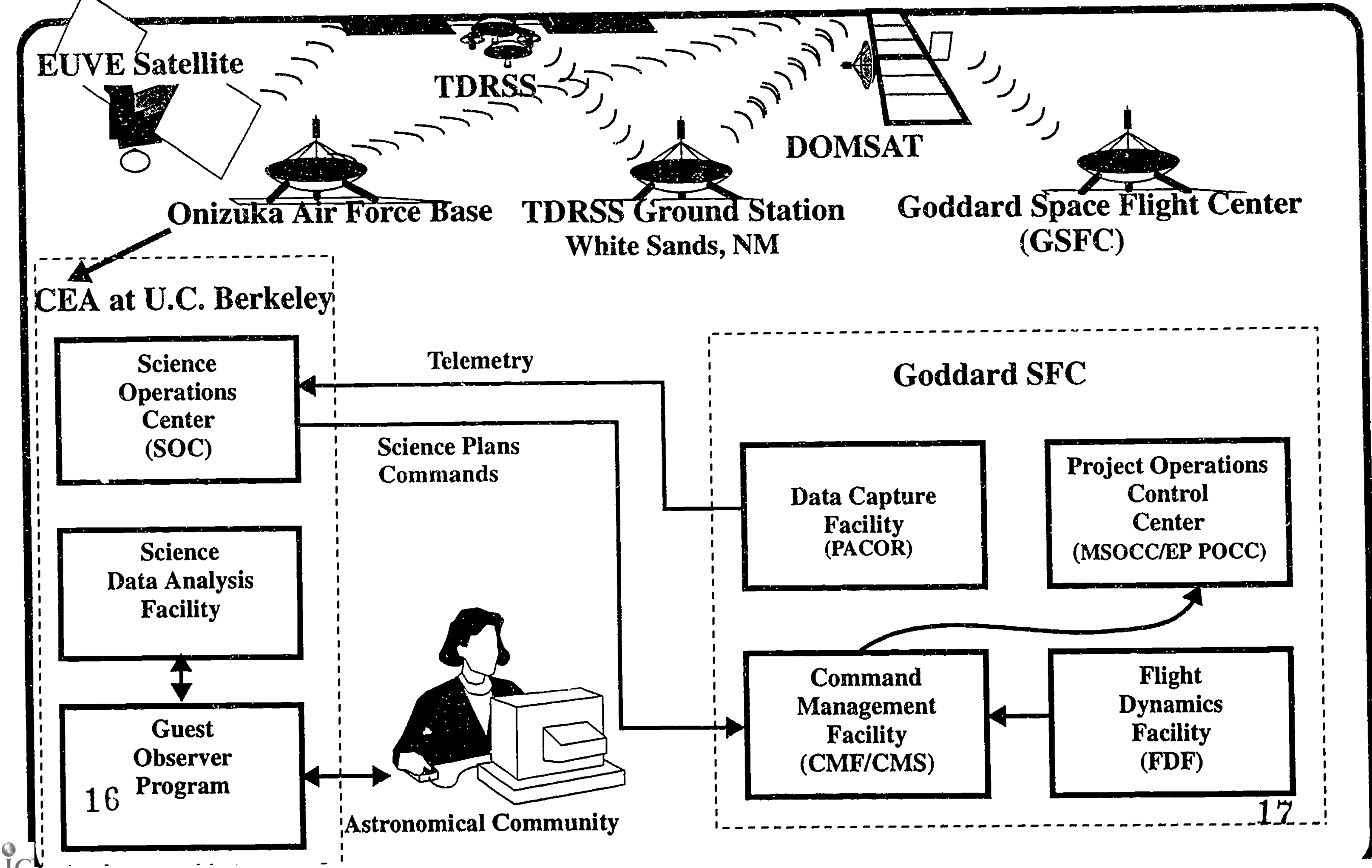
The EUVE satellite must relay the starlight it detects to the Earth via telemetry (relayed radio waves) so that scientists can analyze the data. This is accomplished by transmitting the detected starlight in binary form through a sequence of additional satellites, ground data-capture and relay stations on the Earth, and telephone lines. This demonstration allows 10 participants to each play one of the following roles:

- Star: A star or other object emitting EUV radiation
- EUVE: Extreme UltraViolet Explorer satellite
- TDRSS: Tracking and Data Relay Satellite System
- White Sands: TDRSS Ground Station, in New Mexico
- DOMSAT: Domestic Communications Satellite
- Goddard: Goddard Space Flight Center, in Greenbelt, MD
- DOMSAT: Another Domestic Communications Satellite
- Onizuka AFB: Air Force Base, in Sunnyvale, CA
- UCB's CEA: UC Berkeley's Center for EUV Astrophysics (CEA) computers
- Scientist: Any scientist throughout the world who comes to CEA to analyze EUVE data

A total of three geosynchronous satellites (the two DOMSATs and TDRSS) participate in this task. The geosynchronous satellites orbit 22,000 miles above the Earth's surface such that they "keep up" with the Earth's rotation and always have direct line of sight to a given ground station. Geosynchronous satellites thus revolve around the Earth once every 24 hours. The EUVE satellite, by virtue of its lower orbit (320 miles above the Earth's surface), revolves around the Earth at a much faster pace - approximately once every 90 minutes. Thus for every complete Earth rotation, EUVE goes around the Earth approximately 15 times. Figure 3 shows a "bird's eye view" of the demonstration. Each small oval and circle represents a demonstration participant. The arrows attempt to signify that each oval or circle is in motion in a counterclockwise direction. The Earth-bound demonstration participants (ground stations, scientist, etc.) start spinning very slowly to allow the geosynchronous satellites (as they "model" revolution around the Earth) to "keep up" with their corresponding ground stations, and more importantly, to allow the "EUVE" to run around at a very fast pace. A ball is used as a physical representation of the "starlight." A successful implementation of the demonstration involves all participants moving in concentric circles as the appropriate relative speeds while the "starlight" is thrown from point to point on its way from space to a scientist at UC Berkeley. This demonstration allows participants to get a kinetic feel for the dynamics involved in satellite communications and orbital motion around the Earth. Participants also have an opportunity to experiment with modeling of fundamental physics and space science concepts, i.e., light travels in a straight line (non-relativistic case), conservation of angular momentum (satellites closer to the Earth revolve faster then those in higher orbit), as well as space science domain knowledge such as what a "geosynchronous satellite." In addition, participants obtain a real sense of the team work and coordination that is required in complex scientific endeavors such as the operations of a NASA astrophysics mission.

FIGURE 1

EUVE SATELLITE DATA FLOW



EUVE Satellite

TDRSS

DOMSAT

Onizuka Air Force Base

TDRSS Ground Station
White Sands, NM

Goddard Space Flight Center
(GSFC)

CEA at U.C. Berkeley

Science Operations Center (SOC)

Science Data Analysis Facility

Guest Observer Program

Telemetry

Science Plans
Commands

Astronomical Community

Goddard SFC

Data Capture Facility (PACOR)

Project Operations Control Center (MSOCC/EP POCC)

Command Management Facility (CMF/CMS)

Flight Dynamics Facility (FDF)

FIGURE 2

Satellite Dataflow Viewgraph

Flow of Data from Star to Scientist

Clicking on the diagram pictures will link to corresponding sites with color pictures:

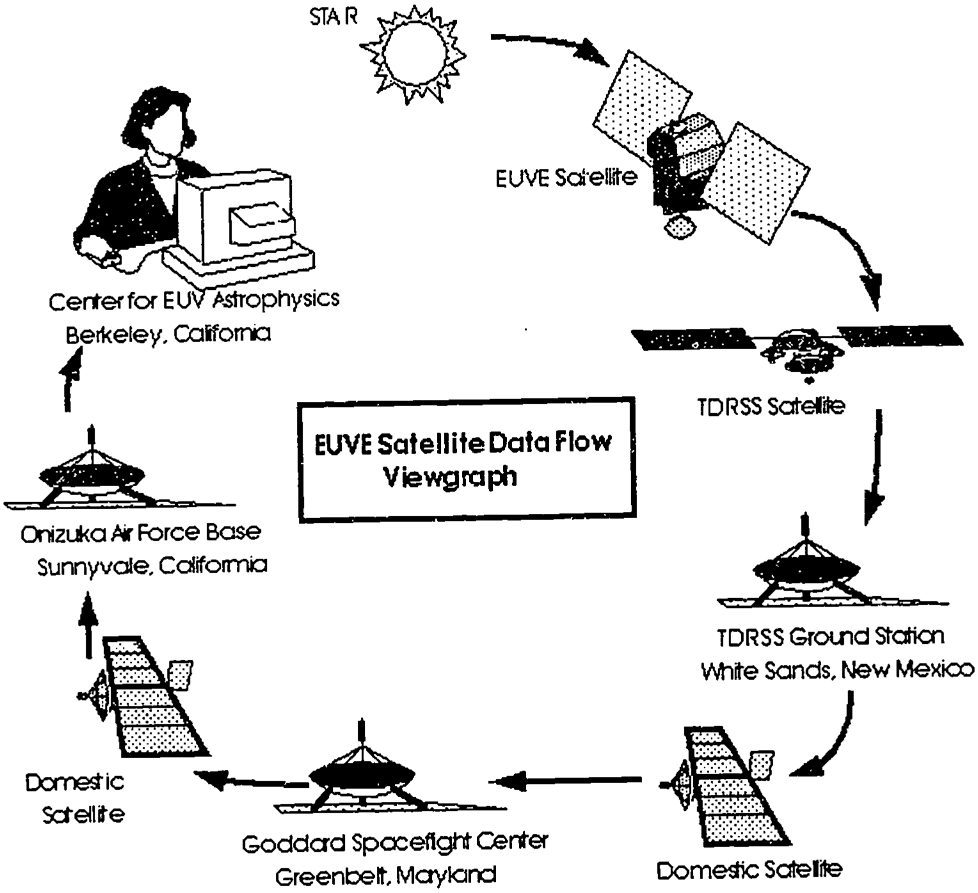


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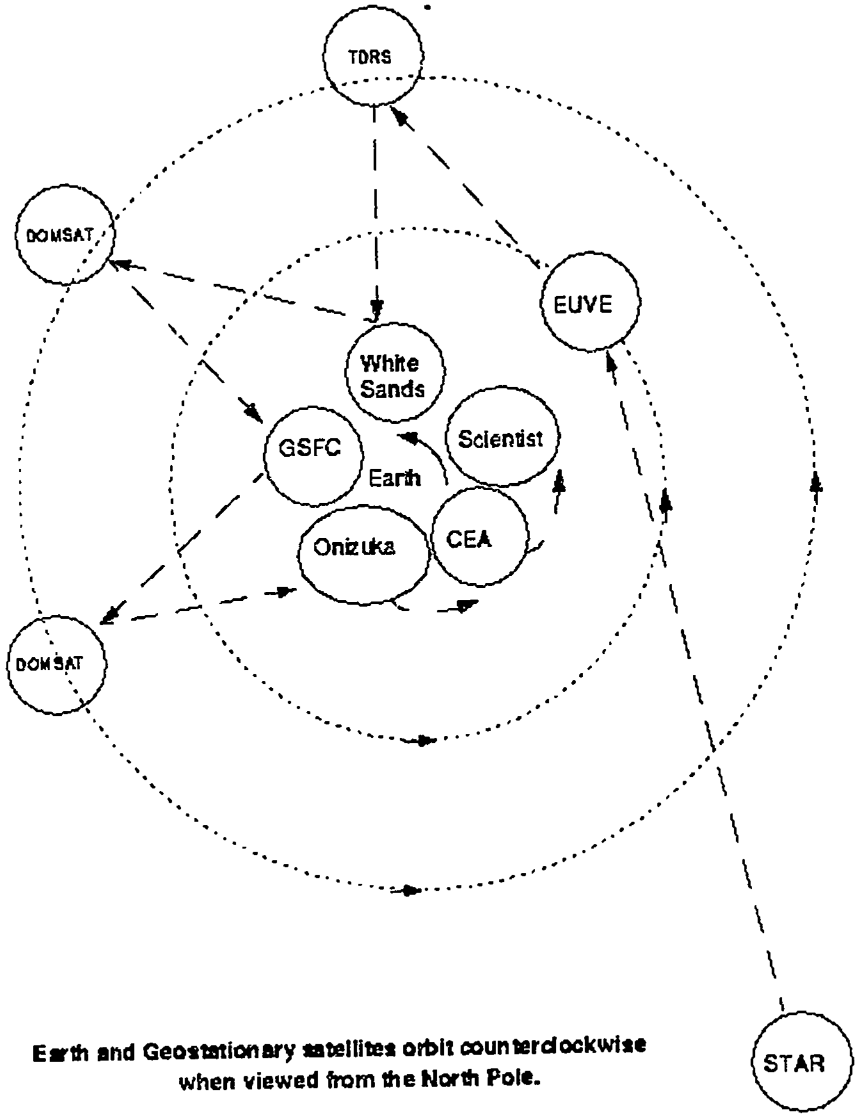
FIGURE 3

Top View of Demonstration in Motion



Earth and Geostationary satellites orbit counterclockwise when viewed from the North Pole.

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