

# “I’ll Get That Off the Audio”: A Case Study of Salvaging Multimedia Meeting Records

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## ABSTRACT

We describe a case study of a complex, ongoing, collaborative work process, where the central activity is a series of meetings reviewing a wide range of subtle technical topics. The problem is the accurate reporting of the results of these meetings, which is the responsibility of a single person, who is not well-versed in all the topics. We provided tools to capture the meeting discussions and tools to “salvage” the captured multimedia recordings. Salvaging is a new kind of activity involving replaying, extracting, organizing, and writing. We observed a year of mature salvaging work in the case study. From this we describe the nature of salvage work (the constituent activities, the use of the workspace, the affordances of the audio medium, how practices develop and differentiate, how the content material affects practice). We also demonstrate how this work relates to the larger work processes (the task demands of the setting, the interplay of salvage with capture, the influence on the people being reported on and reported to). Salvaging tools are shown to be valuable for dealing with free-flowing discussions of complex subject matter and for producing high quality documentation.

**KEYWORDS:** activity capture, audio recording, multimedia, LiveBoard, meeting support tools, notetaking, salvaging, work process support

## MEETING CAPTURE AND SALVAGE

Our interest is how computational tools can support the natural, informal activities that are inherent in human collaboration. The aim of the research reported here is to create tools (1) to support and capture the free-flowing activities of meetings and (2) to utilize the captured multimedia meeting records effectively in the larger work processes in which the meetings are embedded.

Meetings are productive because of their interactional character. The rapid give-and-take of conversational exchanges produces insights and shared understandings. However, it is often difficult to document the content and process of meet-

ings. The result is that there are lost opportunities to make later use of much of the content—insights, subtleties, perspectives, needs, decisions, reasons, caveats, and so forth—expressed at meetings, as well as the modes of expression (enthusiasm, caution, etc.). We are exploring one approach to this problem: to capture not only the written artifacts of the meeting, such as prepared materials and notes taken at the meeting, but also audio and video records of the course of activity of the meeting. Multimedia records provide a rich resource with which to revisit the course of the meeting, to reexperience and reinterpret its details, tenor, and tone. Our goal is to understand how multimedia records can be used.<sup>1</sup>

Documenting meetings (e.g., taking minutes) is a common task. Some people already use recorded materials, e.g., reporters who routinely use audio recorders. But new technologies for capturing, indexing, and accessing multimedia records can expand the ways with which recorded materials can be worked. We call the new activity of working with captured records “salvaging.” The research challenge is to understand the nature and efficacy of this new kind of activity and how it can be evolved into effective work practices.

Much of the emerging research in multimedia capture seems to take a cognitive view of capture and salvage as a memory aid, such as studies testing the retrieval of answers to specific questions (e.g., [7,15]). While we agree that there are research issues of human memory, our view is that the capturing and salvaging of meetings needs to be understood within the social and organizational context of the larger work processes. The development of effective practices of capturing and salvaging meetings must be done by interrelating them with other work practices.

Consistent with this orientation, we have devoted much of our research to a particular case study, where we create and explore the use of capture and salvage tools in the context of

1. We want to emphasize that we are exploring multimedia in order to help people cope with the complexity of freeflowing discussions. Media recordings are commonly used for quite different reasons: for accountability, such as in legal processes (“anything you say can be held against you”) and security (surveillance). This is the very opposite of what we are trying to achieve. We don’t want to inhibit people by making them feel accountable for every statement, but rather we want them to feel free to discuss ideas and be able to revisit them. Thus, trust and understanding of how captured records are to be used is crucial.

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a real ongoing work process. The value of this approach is that we can participate in the co-evolution of tools and work practices that are effective in the work setting and can thus understand how these kinds of tools fit into the social context of an extensive work process.

### WHAT IS SALVAGING?

Meetings consist of *activities*, such as speaking, writing on the board, taking notes, moving around, coming and going, laughing, pointing to materials, and so on. These activities can produce various *artifacts*, such as drawings from the board, written notes, etc. Audio/video recordings created when the meeting is captured become additional artifacts. It is crucial that meeting capture tools also produce *indices* that can be used during salvaging to access the specific activities of the meeting for replay. In our case, we use timestamped representations resulting implicitly from the meeting activities, such as taking notes, changing displays on the board, speaker changes, etc.

The central activity discussed in this paper is what we have called *salvaging* (in the dictionary sense of “saving for further use”). It involves culling through the artifacts of a meeting to dig up useful pieces, indexing them, relating them, rechecking them, organizing them, and creating new materials with them. The notion of salvaging is richer than just retrieval or browsing—it is an active process of *sense-making* [12] of the meeting and making the important parts of the meeting more easily accessible to potential *consumers*, who simply want to “read” about the meeting.

The concept of salvaging, versus simple consuming, is valuable when the artifacts of capture are not themselves easily consumable.<sup>2</sup> In many important meetings, the process and/or content is too complex, subtle, inarticulate, and/or chaotic to allow the creation of accurate or understandable meeting artifacts in real time.<sup>3</sup> The best the meeting participants can do is create adequate indices into the activity to support later salvaging.

The salvager’s goals can vary considerably, depending on the anticipated consumers and their needs. The salvager might want to simply “clean up” the meeting artifacts to serve as meeting minutes. Other salvaging goals include clarifying the rationale for meeting decisions, clarifying the attributions of ideas, putting meeting statements in context, and filtering out sensitive parts of the meeting record.

Salvaging can produce a wide range of artifacts that address different kinds of consumers. The simplest artifact is a text report, which makes for quick consumption. Or the salvager might want to create an index to allow a consumer to selectively replay parts of the meeting. In this case, the salvager might just need to clean up and more accurately timestamp the notes from the meeting to serve as good entry points for

2. Part of our current research is exploring tools that automatically identify and present artifacts from meetings on the Web with little or no intermediate salvaging effort.

3. It should be pointed out that we do not claim that all meetings are worth salvaging. An interesting phenomenon we have experienced is that it is often difficult to know until after a meeting whether there might be something worth salvaging.

playback. Or the salvager might want to go all the way and create an elaborate multimedia presentation of the meeting or set of meetings. In this extreme case, the activity of salvaging is like multimedia authoring. In general, however, we believe that most salvaging is oriented more to sense-making artifacts than to high-production-value presentations.<sup>4</sup>

Salvaging performance varies substantially depending on multiple factors, such as whether the salvager was present in the captured session, the salvager’s expertise with the technology, the salvager’s familiarity with the material being discussed, the salvager’s goals, and the type of event or meeting captured. We will report on our studies of these dimensions of use and how they shape different salvaging behaviors in a future paper. The present paper focuses on a case study involving one salvager over a long period with evolving expertise and utilizing materials of differing familiarity.

### RELATION TO OTHER RESEARCH

We have been working on capture and salvage tools for many years, beginning with the *WhereWereWe* system [8] (which focused on playback during the captured event itself). We reported on the need for a “confederation” of cooperating tools to achieve effective capture in meeting settings [9]. We reported on our longitudinal case study of these tools in a real setting in [10]. However, in [10] we focused on the issues of capture; in this paper we focus on the issues of salvaging.

Schmandt and his colleagues have been working for many years on making audio usable. In [4] they explore ubiquitously capturing audio in the work environment, and they show techniques for accessing the audio. Using the strokes on a sketching application to index captured audio (and video) was first reported in the *NoTime* system [7]. The *Filochat* system [15] used stroke indexing for notes taken at meetings. The *Audio Notebook* [14] is a paper-based portable notetaker that indexes captured audio. All of these are oriented as personal tools.

More elaborate collaborative systems are also being explored. The Bellcore *Streams* system [2] focuses on capturing the audio and video of formal presentations in an auditorium setting. Various automatic video and audio indexing techniques are used to create timeline-like views of the presentations. The *Jabber* system [5] captures video conferencing meetings. The research is focused mostly on indexing the content of the meeting by putting the audio stream through a speech recognizer and then applying a lexical analyzer to build a tree of keywords that provide an index structure into the audio/video records. *Classroom 2000* [1] is a preliminary effort at capturing the presentation materials and the audio in the classroom, using a LiveBoard for presentation and palmtops or laptops for student notetaking.

There are a couple of empirical studies. In [16] there is a

4. Salvaging is also quite different from the activity of sequential data analysis [13], such as video analysis. A data analyst’s goal is to create a detailed account of the course of activity. Salvagers are more interested in the content and in extracting the valuable parts and the context necessary for understanding those parts.

brief study of people searching for specific events in videotapes of real meetings using a VCR, showing some of the strategies they employ. Whittaker et al. [15] ran an experimental study of *Filochat*, showing that indexed audio supported better recall, but took longer (there is a similar result in [5]). [15] also reports a naturalistic study of *Filochat* usage in nine meetings, and there were indications that different people found it useful to “salvage” the meetings. However, the evidence in the current literature about the nature and utility of salvaging is scant.

## THE CASE STUDY

We have put our capture and access tools to use by engaging with an ongoing work process at Xerox PARC, the management of intellectual property. This is not a controlled study, but a naturalistic, longitudinal study where the use of the tools was determined by the demands of the work process.

## The Work Process

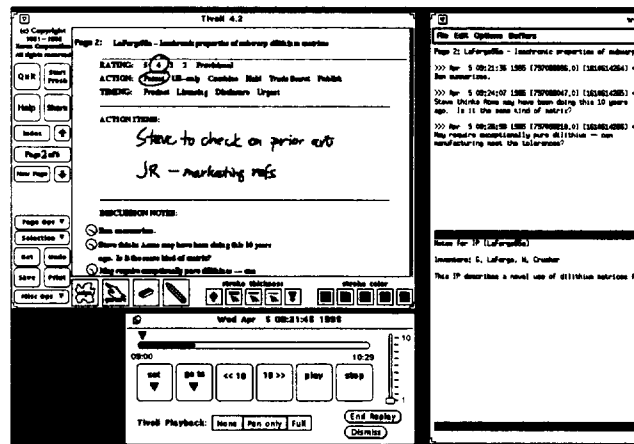
PARC's management of intellectual property is a complex, ongoing process (see [10] for a more complete description). Researchers are encouraged to submit *Invention Proposals* (IPs) describing their inventions, which are evaluated by peer review via *Technology Assessment Panels* (TAPs) of technical experts from the labs. There are several TAPs covering a wide range of technical domains, such as solid state devices, large area electronics, image processing, software architectures, software applications, and user interfaces. TAPs meet on a regular basis to review submitted IPs, and the results are reported to inventors, managers, and patent attorneys.

The central figure in this process is the coordinator of the process (we call him *C*). His job is to keep the process running smoothly, report to management on the status of intellectual property, and look for ways to improve the quality and quantity of intellectual property by refining the process and adapting better technological support.

There are two settings on which our project focuses: the TAP meeting and *C*'s office, where he writes his summaries of the meetings. *C* calls the TAP meetings, in which an average of 6 members review an average of 6 IPs. The members bring their annotated copies of IPs to be evaluated. In the meeting they consider each IP in turn, discussing its value along many dimensions. There is much give-and-take in the discussion, and members' views can change considerably in the process of trying to reach a consensus. The discussions average about 15 minutes. They give each IP a summary rating, but there are always caveats, suggestions, and actions. *C* manages the agenda, facilitates the IP discussions, brings the group to consensus, and takes notes on the discussion.

*C*'s most critical task is then to create reports summarizing each IP and its assessment. These reports provide feedback to the inventors, inform the managers and attorneys about new intellectual property, and help TAP members who periodically prioritize the corpus of IPs. Creating accurate reports is an extremely challenging task for two reasons. The first is the technical breadth, depth, and subtlety of the subject matter in the TAP discussions. Although *C*, a physicist, was formerly a researcher and is thus knowledgeable about

Figure 1. Salvage Station Display.



some of the technologies, he is a novice at others, such as software. Second, because of his workload, *C* is often not able to work on a report until a month or more after the TAP, by which time it is difficult to rely on his memory and his notes are difficult to interpret.

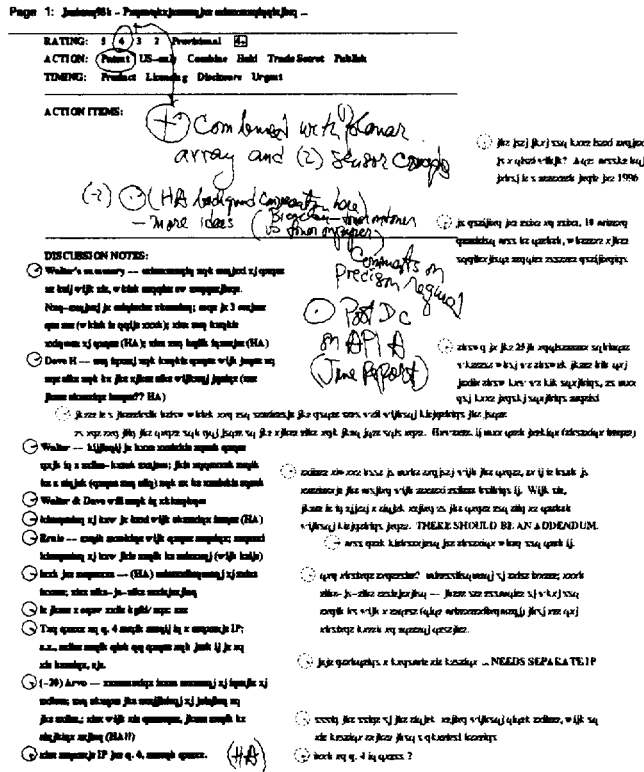
## Capture and Salvage Tools

In this study, capture took place in the group setting and salvage in the individual setting. For the group, we set up a regular PARC meeting room for the TAPs. There was a large table with audio microphones and a LiveBoard [3]. *C* sat near the end of the table, so that the TAP members could easily interact directly with each other. We set up the following “confederation” of activity capture and salvage tools [9,10]:

The LiveBoard ran the *Tivoli* whiteboard application [11] to display pages of materials to support each TAP meeting. The first page held the agenda of IPs, followed by a review page for each IP on the agenda. The review page provided a form to record the rating, a space for writing actions, and a space for notes of the discussion of the IP. A *Tivoli* review page is shown in the upper left window of Figure 1. Every action in *Tivoli*, such as switching a page (signaling that the TAP's attention was moving to another IP) or making a stroke with the LiveBoard pen, was timestamped by *Tivoli*, providing index points into the audio record. *C* preferred to take discussion notes with a keyboard at the table. So we provided a laptop with our own notetaking application [9], which timestamped the notes and dynamically “beamed” them and their timestamps onto the Liveboard, where the TAP members could scan them. The timestamp for each note appeared in *Tivoli* as a *clock icon*. During discussions, *C* typed a note, consisting of 1-5 lines, about every 2-3 minutes.

For the individual setting, *C* was provided with a “salvage station” in his office. The salvage station interface, shown in Figure 1, presented the *Tivoli* display, a set of playback controls (play, stop, and forward or backward 10 seconds), and a word processor for creating the IP reports. The salvage station provided *C* with random access into the audio at the index points. The main indices were the pages. By going to the *Tivoli* page for a particular IP, *C* could play the discus-

Figure 2. Sample of Salvage Annotations. Annotations added during the salvage session are grey (red in the original). Text is "encrypted" to mask proprietary data. (Salvage on 11/17/95 of TAP meeting on 10/23/95.)



sion of that IP. Within the page, C could use the beamed and handwritten notes as indices. Gesturing on any clock (in front of a beamed note) or stroke caused audio to play.

C could also use Tivoli as a workspace to create further annotations and indices during salvaging. When a clock was created during salvaging, it indexed the current playback time. Annotations could be typed or sketched anywhere on the workspace, since Tivoli is a freeform editor. Figure 2 shows an example of a salvage artifact created by C. The typed notes on the left were from the meeting. The clocks and annotations to the right were added during salvaging.

Note that we are concerned in this paper only with the capabilities of salvaging tools, not with the details of their user interfaces. User interface issues will be discussed elsewhere.

Method

Conditions. We studied C's salvaging process under naturalistic working conditions. The volume and complexity of C's job as manager of the IP evaluation process kept him extremely busy. We wanted him to fit our tools into helping with the demands of his job; we could not afford to impose a new routine on him under the guise of experimental control. C managed his own schedule. The salvage tools were made available to him for report writing in his own office. Although the use of these was left to his discretion, he did incorporate them into his routine work practice.

C's report writing for a given TAP was distributed across sessions, locations, and tools. He would work when he could find the time, he sometimes took work home, and he sometimes worked on the text of reports without the need for salvage tools. Our study focused only on the sessions where he used the salvage tools.

Data. We used four sources of data in this study: (1) We collected all the meeting and salvage artifacts (e.g., Figure 2). (2) The salvage tools were instrumented to produce time-stamped logs of all user interface operations. (3) We interviewed C several times in his office (so he could refer to materials he used); these interviews were audio taped. We also had frequent informal discussions with C. (4) Finally, we videotaped his salvage sessions. Cameras were mounted in his office, and we provided a dedicated VCR. C was very cooperative and started the VCR every time he salvaged.

Time Span. We first installed the capture and salvage tools in 1/94 [10], and they have been in continual use since then. The present study of C's salvaging work focused on the period 3/95 to 12/95.

CASE STUDY FINDINGS

We present findings showing the intricate nature of salvaging work, how C's practices developed over time, and how C responded to different content domains.

C's salvaging practices were fairly stable at the beginning of the study period, which we call his "early" phase (by which time C already had over a year's experience with the tools). However, new practices emerged near the end of the study period, which we call his "late" phase. We present here three salvaging sessions representative of these phases and of the diverse content domains he works with. The differences in C's work practices can be described in terms of his strategies and pattern of activities.

Salvaging Strategies

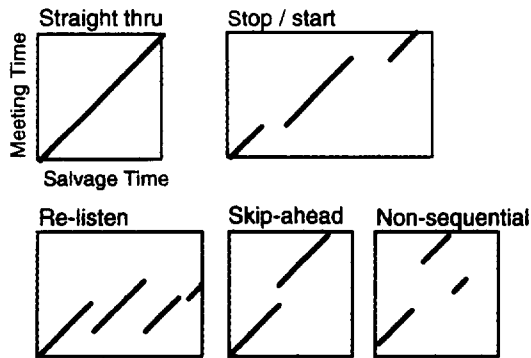
C developed multiple salvaging strategies for working with the captured meeting materials and creating his final reports. These include:

- 1. Writing the final report while listening to the captured audio record and reading the meeting notes.
- 2. Creating annotations and audio indices in the meeting record while listening to the audio.
- 3. Writing the final report from textual notes only (meeting notes and any additional annotations).

C employed these strategies in response to different conditions. For example, he used strategy 3 when he had a particularly simple TAP (on a familiar topic). Strategy 1 was employed mainly in his early phase, and he began to use strategy 2 in his late phase. Strategy 3 was used to follow on the results of strategy 2.

5. We provided a separate Sun workstation as the salvage station. C used a PC for most of his work. Although the integration was not ideal, C was able to get data from one workstation to that other. Most important was getting data into Lotus Notes, which held the IP database.

Figure 3. Profiles of Listening Patterns.



### Listening Profiles

Different salvaging strategies result in different patterns of activities, such as reviewing notes from the meeting, creating new text, choosing which part of the meeting to listen to, and so on. We have found it useful to represent the pattern of activities on a *salvage profile*, which plots the salvager's activities on a graph with two timelines, the timeline of the salvage session (horizontal axis) and the timeline of the meeting being salvaged (vertical axis). A characteristic salvaging activity is listening to a playback of the recorded audio. A profile showing the listening activities is called a *listening profile*. Listening activities are shown as 45 degree lines (indicating that the audio playback is at normal speed).

Figure 3 shows how listening profiles portray different patterns of salvaging activity. The baseline pattern is to listen to the audio straight through from start to finish. Salvagers often stop and restart the audio, they skip segments of audio, and they relisten to segments of audio. Note that these four patterns are all *sequential*: the salvager is basically conforming to the sequential unidirectional structure of the audio. The last pattern is non-sequential listening. In real sessions, we see mixtures of these listening patterns.

Listening profiles of three of C's salvage sessions are presented in Figures 4-6. These profiles have additional information. The dashed horizontal lines show how the TAP meetings were divided into segments discussing different IPs. The grey areas highlight the fact that C's listening pattern shows that he systematically attended to one IP at a time while salvaging. On the right of the profiles of the first two figures are graphs plotting the number of times each segment of the meeting audio was played during the salvage session.

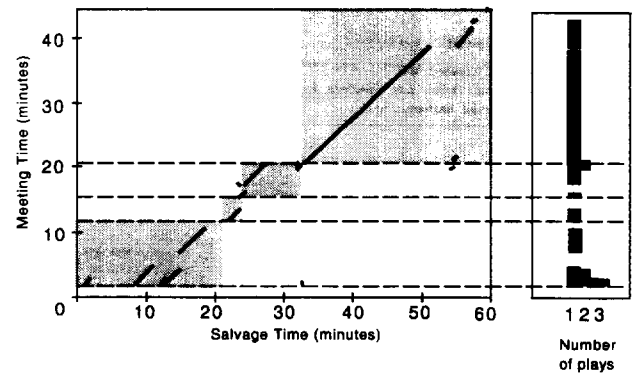
### Early Salvaging Phase

The two salvage sessions in Figures 4 and 5 are typical of C's early phase. The first session deals with a software TAP and the second with a physics TAP. Because of C's heavy workload at that time, both of these salvage sessions lagged their TAP meetings by about two months.

Note that in both of these sessions the pattern is sequential. C salvages the IPs in the order they were discussed in the TAP meetings. Within IPs, he proceeds through the meeting audio sequentially, with no skipping around. A sequential strategy is the safest way to navigate through the audio data. It makes

Figure 4. Listening Profile of an "Early Software" Salvage Session.

(Salvage on 5/19/95 of TAP meeting on 3/22/95.)



it easy to keep track of what has and what hasn't been salvaged. Jumping around the audio in a non-sequential fashion requires other props for keeping track.<sup>6</sup>

C's strategy in both of the early sessions is to type the report in the word processor while simultaneously listening to the audio (we can see this in the video data). He goes straight to text by *actively listening* to the audio and using the meeting notes and his own recall. Other features:

### Features of the Early Software Salvage Session (Figure 4):

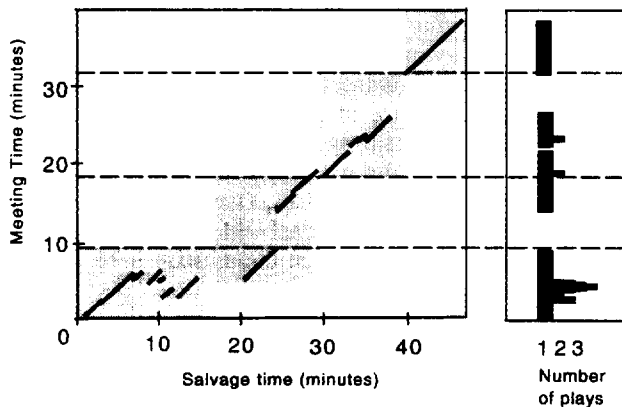
1. C listens to almost all of the audio of the meeting.
2. The listening pattern shows stops and starts. For example, at around salvage minute 30, C stops for about six minutes. He heard the discussion of the third IP wind up; he then consulted the hardcopy of the IP and completed the text of his report before going to the next IP.
3. C replays the audio, but only a little. For example, at about salvage minute 10, C relisten to the first part of the audio. During his first listen, he paraphrases the gist of the discussion in the report; then he goes back to relisten for some better phrases to improve his text.
4. While he types the report, he lets the audio play continuously in the *background*, as can be seen at salvage minutes 35-50. Continuous play allows him to listen for important points while also ensuring that he gets total coverage of the material.

### Features of the Early Physics Salvage Session (Figure 5):

1. In contrast to the software session, C does not listen to all of the audio. For example, he skips a large segment in the third IP; he decided from what he had listened to that he had heard enough.
2. He repeatedly listens to a particular segment of the meet-

6. A detailed examination of the video of this session revealed that C did attempt to salvage the IPs in a different order, using a hardcopy agenda as a guide. However, the meeting did not follow the order of the hardcopy agenda; and C was very confused. He found it easier to conform to the natural sequential structure of the audio medium to order his work.

**Figure 5. Listening Profile of an "Early Physics" Salvage Session.**  
(Salvage on 5/12/95 of TAP meeting on 3/8/95.)



ing audio in the first IP. For example, at salvage minute 10 he relistens in order to check the text he just typed. He also creates a clock to index the replayed segment.

3. There is an interesting case of faulty navigation in the audio in the second IP. C starts on the second IP by typing some text (salvage minutes 17-21), and then he wants to listen at minute 21. Instead of gesturing on a clock, he simply presses the play button, which plays the audio from the last playpoint, which is still in the discussion of the first IP. It takes C a few seconds to realize that audio is from the first IP. He decides to let the audio play out while he occupies himself by organizing papers and by typing some initial text for the second IP. By the time he hears the discussion of the first IP coming to an end (minute 25), he has read the meeting notes for the second IP and decided that the important point is in the fourth note, so he gestures on the fourth clock to skip to that point.

### Late Salvaging Phase

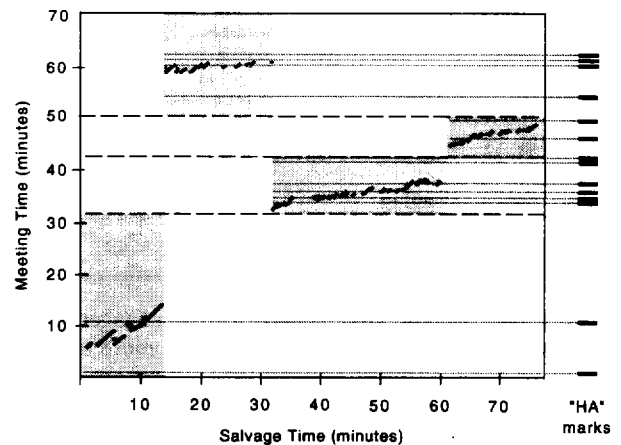
Figure 6 presents a listening profile of C's salvaging a software TAP meeting 8 months later. This profile reveals an advanced salvaging practice. From the video data, it is also apparent that C's behavior is quick and skilled, with a dense mix of activities.

C was very focused, as he approached this session only 3 days after the TAP with the issues he wanted to deal with fresh in his mind. C's strategy was to work carefully at understanding particular segments of the meeting and with compiling additional notes, which he added to the workspace on Tivoli (as in Figure 2). He would then use these in a later session to write the actual IP reports.

#### Features of the Late Software salvage session (Figure 6):

1. In contrast to his early phase, C does not follow the meeting order in salvaging IPs. He skips from the first to the fourth IP, apparently because this was the order of IPs on his hardcopy of the meeting notes.
2. C listens to only a small fraction of the audio record.
3. C replays relevant segments of audio over and over. He

**Figure 6. Listening Profile of a "Late Software" Salvage Session.**  
(Salvage on 12/2/95 of TAP meeting on 11/29/95.)



backs up and relistens to short segments while transcribing the spoken words next to the meeting notes. C also creates clocks to mark the points where some of his transcriptions begin. For example, in the third IP, C very carefully transcribes a particularly technical description of software logic.

4. C has evolved special marks in his meeting notes to locate the relevant audio segments. The mark is "HA" (for "hear audio"). (See Figure 2 for examples of HA marks.) During the meeting, C would type HA to signal points he thought were important, well-articulated or difficult to understand, anticipating that he would want to revisit them during salvaging.<sup>7</sup> Figure 6, on the right, shows when the HA marks were created in the meeting. It can be seen that C uses the HA marks to focus his listening activity. In some cases, the points he marked are no longer relevant to him. In other cases, he uses the approximate location of HAs to localize his salvaging activities.

In a later session, C used these salvage artifacts to write the actual IP reports. We examined his final reports and found that about half the notes he transcribed in the salvage session were incorporated fairly literally into his final IP reports and constituted a significant portion of the resulting text.

### Salvaging Different Content

During interviews, C told us that he felt much more at ease dealing with the content material of the physics TAPs than the software TAPs. Familiarity with content appears to be a strong determinant of the kind of salvaging strategies C employs. These strategy differences became more pronounced over time. In the early phase (Figures 4 and 5), we see that he felt the need to listen to the audio of software TAPs more completely. In his late phase, where he was trying to be more prompt and focused in his salvaging, the dif-

7. C also used HAs to mark parts of the meeting that went too rapidly to take notes on. For example, in this session C marked a time when a list of specific items was being rattled off; this list was transcribed during salvaging and included in the report.

**Figure 7. Three Measures of Salvaging in Different Content Domains.** (The measures are averages per IP. A-D represent different TAPs.)

	Physics		Software	
	A	B	C	D
Written references to audio during the meeting	.29	.40	1.51	1.29
Annotation "chunks" created during salvaging	.00	.00	.63	.95
Clocks created during salvaging	.00	.00	.49	.29

ferences have become more pronounced. C engaged in more elaborate indexing and salvaging and made more use of the salvage artifacts in the software TAPs. Figure 6 shows C digging deeply into selected parts of the meeting audio to understand the technical arguments, during which he creates further annotations on the salvage artifact. These activities do not occur while salvaging the physics TAPs.

We have not presented an example of a late physics salvage session. Instead, we show the differences between the two content domains in the late phase with some summary data. The differences are clearly revealed by comparing measures of various activities across a number of late phase TAPs. The measures are: the number of explicit written references to the audio C creates during a TAP meeting; the number of "chunks" of textual annotation C adds to the salvage artifact while salvaging; and the number of clocks he creates on the salvage artifact. We counted these features in C's salvage artifacts for a span of ten months (9/95–6/96) in four different TAPs, two physics TAPs and two software TAPs (balanced for frequency and dates). The table in Figure 7 confirms that C hardly ever engages in the more elaborate salvage activities when dealing with the familiar physics content domain. In fact, C claims that he often does not need to use the audio to report on the familiar physics TAPs. The salvage tools are more valuable—indeed crucial—for dealing with difficult and unfamiliar materials.

#### FURTHER OBSERVATIONS ON SALVAGING

The case study raises a multitude of general issues; many of these are concerned with the relationship of salvaging to other people and work in the larger work setting.

***Evolving Practices for Efficiency.*** We saw in the Late Software salvage session that C uses the audio in a very focused way to, as C says, "mine for gold." He localized his search for valuable pieces of information by flagging those ideas during the meeting by using HA marks. Creating and using HAs is a practice that has evolved over time. Early in his use of capture tools, C would often say during a meeting, "I'll get that off the audio", which signalled to the TAP members that C knew something important was being said, even though he didn't take full notes on it at the moment (he was frequently in the middle of typing an earlier note). However, this utterance was not something he could later use as an index into the audio. To create a useful index, he eventually

began writing explicit audio references, such as "hear audio," in his notes during the meeting. One meeting later, he shortened this to "HA" and added HAs to his regular note-taking vocabulary. Other factors converged to make this practice work. C was making a special effort to be efficient and to eliminate the delay in producing reports. By starting to salvage soon after a TAP meeting, C was more prepared to interpret the significance of the various HAs and hence to use them effectively in salvage sessions. The development of the HA convention and the strategy for using it is a prime example of his evolving practices. Over time he developed many specialized strategies to deal with the particularities of the different TAPs and different circumstances he encountered in the work process.

***The Salvage Artifact as a Workspace.*** C deals with many artifacts during salvaging: both in hardcopy (the IP, the meeting notes, email) and on the workstation display (the meeting notes, the draft text of the report), as well as the audio record. Managing and coordinating these resources is part of his salvaging task. One way to organize the various resources is to move any relevant information from all sources into the report. However, C found that it was better to have an intermediate place to assemble information during salvaging. He did this by adding annotations to the workspace containing the meeting notes. From an interview with C, we can discern that he did this to limit the complexity of having to simultaneously deal with two different places, two different organizations, and two different tasks.

C uses the meeting notes to index into the audio. He is focused on this display window and not on the report window. The meeting notes are ordered by the discussion in the meeting, and he follows the discussion order to salvage, whereas the draft outline of his report is often in a different order. C says he is "fishing for information" when salvaging, and it is better not to try to organize the information at the same time. Further, C claims that as "you listen to the material, you change the organization it is finally going to go into ... so it is better to ... get all the fish out before you try to work with them."

***Speed/Accuracy Trade-Off.*** C must balance the time he spends on his writing and the thoroughness and accuracy of his reports—the classic speed/accuracy trade-off. Capture and access tools allow, even encourage, greater accuracy. Whittaker's study [15] showed that retrieval from captured audio was more accurate, but his subjects stopped short of 100% accuracy (retrieval just took too long). The larger work context is a strong determinant of where to strike the balance. For example, for a period of time C experimented with "quick reports" (brief reports produced without salvaging), but these were not acceptable to the inventors, who wanted more detailed feedback. So C returned to more detailed reporting. Salvage tools do not determine a particular place on the speed/accuracy trade-off; it is up to the user to manage this. Good tools can alter the trade-off curve somewhat, but perhaps more important is that they allow users a greater range of possible places on the trade-off. The utility of capture and salvage tools in a given work setting must be understood in part by the speed/accuracy demands.

**Salvaging as a Channel of Communication.** We saw in the Late Software salvage session that C sometimes carefully transcribes the words of TAP members, especially on topics less familiar to him; and he uses these transcriptions in his reports. The practice of borrowing words from the audio produces an accurate report of the TAP discussion, which is appreciated by the inventors. But it also has interesting effects on the TAP process. We reported in [10] that there is an awareness of the audio in TAP meeting and that TAP members often seem to "speak to the record," that is, they address C in his future role as salvager as much as in his current role as meeting facilitator. They are confident that C will "get it" later, even if he doesn't at the moment. The result of creating such accurate reports of the discussion is that there is no longer a need for TAP members to critique drafts of the IP reports (something they needed to do frequently before the use of our tools [10]). One TAP member commented to us that C's reports using our tools better represent the *diversity of opinion* that is expressed in TAP meetings. This is important not only for the richness of the reports, but also for the satisfaction of individual TAP members, who see their contributions being explicitly used.

By being fairly literal in his reporting, C is attempting to use the language that both the TAP members and the inventors speak.<sup>8</sup> He is acting as a channel of communication between them without distorting the signal. This implies that it may be appropriate for the literal record itself to be transmitted, that is, that salvaging could produce a multimedia report, appropriately filtered, that directly and vividly communicates the richness of the discussion in the meeting. This is indeed one of the goals of our current and future work.

**Design Implications.** The longitudinal study of one naturalistic salvaging context reported here (together with other studies to be reported in a later paper) begins to provide insights into important characteristics of salvage tools. Let us note two design implications (among many) for salvage tools. First, tools should provide a workspace to collect and integrate information. The workspace should serve as a "staging area" for organizing the information, but not require that the information be organized as it is assembled. Second, tools should provide ways for a salvager to manage, structure, and control the salvage process itself. In particular, better tools for orienting and navigating within the audio channel are needed. We have prototyped an improved timeline tool that identifies who is speaking [6] and other meeting activities (e.g., notetaking, page turning). It would also be valuable to indicate which portions of a meeting's audio were played in this (or previous) salvage sessions.

## CONCLUSION

We have demonstrated a real-world use of tools to capture free-flowing discussions of complex subject matter and salvaging tools to produce high quality documentation. These tools are still in use and have become a vital part of the work process. We have described the nature of salvaging in prac-

8. In fact, reports in the software area are now longer and more detailed than in physics, where C is comfortable paraphrasing and condensing without losing meaning.

tice and how the practices evolve; we have observed some general features of salvaging activity; we have suggested some design implications for supporting salvaging; and we have shown that salvaging cannot be thought of as an isolated task, but that it is intertwined with the capture setting.

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