

# **REDLINE - Real-time Documentation Linking Images and Notations Electronically**

**Thomas H. Mills**  
Virginia Tech  
Blacksburg, Virginia

Real time archival of as-built documentation is currently possible and is being used during the construction process. Compilation and retrieval of accurate as-built documentation has always been a problem for designers, constructors, and owners. This problem can be overcome by utilizing the process described in this paper. Within the paper a strategy and appropriate technology for creating and tying electronic as-builts with computerized project scheduling is described. REDLINE assembles low cost portable video capture technology and Microsoft Project 4.0 software to record and link real time construction activities with manual and CADD (Computer Aided Design & Drafting) project drawings. Construction activities are video taped and visually linked to project drawings, details, and task activities through Microsoft Project. The digital information is "redlined" with text and graphics to convey as-built information and is retained for archival purposes. Video documentation is accomplished with minimally trained personnel as is linking video images to project task. CADD prepared drawings and details allow linking with an ability to "redline" as-built conditions. Digital conversion of manually prepared drawings remains a challenge as does disk storage capacity. Archived electronic as-built documentation implemented on a real time basis is achievable and effective. Easily retrievable archived information provides distinct benefits for designers, contractors, and owners. Each participant meets contractual obligations and can subsequently utilize the process to produce a peripheral database addressing their own unique situations

**Key Words:** CAD, CADD, As-built drawings, Record drawings, Scheduling, Digital image linking, Integrated database, Electronic data interchange

## **Introduction**

Record drawing is the AIA recommended term for what contractors commonly call "as-builts." A record drawing or an "as-built" is a construction drawing that has been revised to reflect significant changes made during the construction process. Therefore it contains information not previously documented on the construction drawings. These record drawings take the form of marked up (redline) prints, or reproducibles that have the pertinent "as-built" information redlined on to them. Of particular importance to owners, who ultimately will be operating and maintaining a facility, is concealed conditions notably routing, depth, and location of underground utilities. These conditions become the major elements of acceptable deviations forming "as-built" drawing information. To maintain accurate as-builts, the record drawings must be noted on a daily basis as each activity occurs.

The term "as-built" is discouraged by professional organizations including the AIA. The reason for discouraging this term is concerns of professional liability regarding accountability in

certifying the accuracy of completed construction. This appears a prudent mechanism in the absence of full time project surveillance by design professionals. The A/E/C industry fully embraces the concept of “as-built” documentation by endorsing standard General Conditions to construction contracts that makes the maintenance of “record documents” a contractual obligation. The concept of “record documents” is broadly defined to include all contract documents, in addition to, change directives, written interpretations, clarifications, approved samples and shop drawings. (AIA A-201, 1987) Typical contractual obligations make the maintenance of “as-builts” a contractor responsibility. The importance of “as-built” documentation cannot be overstated. Designers and owners stress the importance of maintaining “as-builts” by making their receipt a condition of receiving final payment.

This paper describes REDLINE (REal-time Documentation Linking Images and Notation Electronically) a process that can be used to record real-time construction activities and subsequently convert this record into electronic as-built drawings. REDLINE allows the user to interactively tie computerized project scheduling and digital as-built images. The model as developed uses Microsoft Project 4.0 for Windows as a self-contained archival source for digital images recording real-time construction progress. The data can further be archived in a read only CD-ROM, thus preserving the integrity of the archived database.

### **Electronic Record Documentation**

Without continuous on-site observation and attentive field supervision the accuracy of “as-built” information suffers. Conditions or information is then redlined or transferred to reproducibles with a graphic quality that renders the information all but useless. This problem has given rise to many owners insisting that the record drawing process become a responsibility of the design professional. This puts a responsibility on the architect to document conditions that they may not have witnessed. This subsequently creates additional concerns on the reliability of “as-built” information.

There is much research being conducted on techniques of digital image processing to record and archive construction documentation. Efforts are being developed to achieve integrated project design and construction information capture within one database. (Vanegas, 1994) The benefit of this activity extends across all the participants and is creating a revolution in the way design/construction integration will occur in the future. On the construction side of the building enterprise project controls are of paramount importance. The most reliable way to implement effective project control is with accurate, reliable, and accessible information. Current strategy uses multimedia as the tool of choice for real-time capture, archival, and retrieval of needed construction process information. MULTROL, jointly developed by the US Army Corp of Engineers and the University of Illinois is a Windows based multimedia information system for documenting and retrieving as-built project information. (Liu, Stumpf, Kim, 1994) This system is directed at an all-inclusive approach to project documentation including text, sound, picture and video sources.

REDLINE follows the lead developed by MULTROL but approaches the process from a narrower perspective using existing scheduling software and low cost portable video capture

technology to record, archive, and retrieve as-built conditions. The captured information, either graphical or visual is then tied back to scheduled activities and project drawings. As concluded by Liu, Stumpf, Kim, and Zbindnen in their 1994 survey, floor plans and as-built drawings were the two most helpful components of construction related information needed in day to day facilities operations. (Liu, Stumpf, Kim, and Zbindnen, 1994) The opportunity presented by REDLINE's narrow focus is the simplicity with which it can be implemented. Until the A/E/C industry is integrated with an Electronic Data Interchange (EDI) standard that is adopted and utilized by the multiple participants, full integration of design/construction data will remain lacking. Electronic as-built drawings are greatly simplified with the use of CADD. Less than 30% of surveyed companies maintain more than 25% of their as-built information in computerized format. (Liu, Stumpf, Kim, and Zbindnen, 1994) With the absence of originally produced digital information or CADD drawings the archiving of electronic as-builts remains cumbersome. Therefore the implementation of the system would only improve with improved exchanges of electronic drawings.

### **REDLINE -- Real-time Documentation Linking As-Built Images and Notation Electronically**

Just as as-built schedules are being used to document deviations from as-planned schedules, as-built drawings can use computerized schedules to allow visual imaging tied to activity starts and finishes. This creates a real-time database for collecting visual images of as-built activities tied back to a digital plan, section, or detail that forms the construction design. This paper explores Microsoft Project 4.0 for Windows as the documentation and archival application for redlining the as-built process. Primavera P3 also has similar capabilities except that the "as-built" image placement is limited to within the Gantt chart or the CPM network.

In simple conceptual terms, REDLINE starts with a computerized project schedule, which list task activities and start dates. Once these dates are established and entered a project documentation schedule can be developed. The next step is to review the drawings and determine a mechanism for digitizing the "record drawings." As previously stated, access to CADD drawings for use as record drawings simplifies a major step in the process. Once drawings are digitized they are then object linked in electronic format to a task activity in Microsoft Project and are visible when viewing the project activity. The original captured image can be redlined and noted as required within its original application to reflect as-built conditions. Figure 1 represents a CADD drawn site plan that has been inserted into Microsoft Project as an "object."

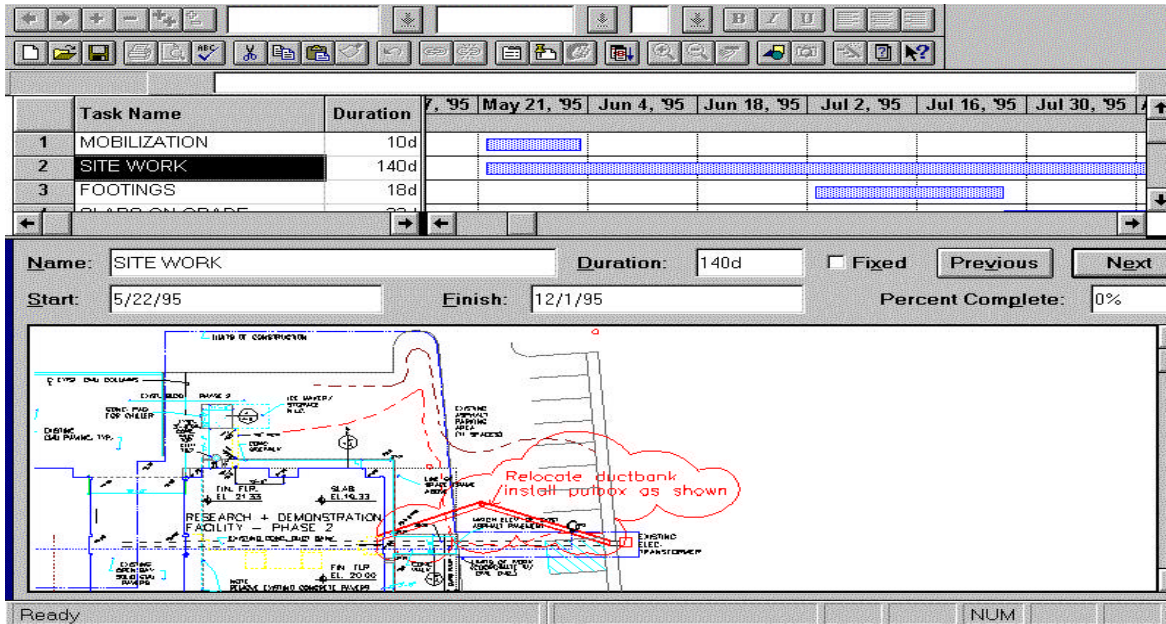


Figure 1. REDlined ductbank

The site plan is attached to the activity “site work” and the routing of the new ductbank is “redlined” within the clouded area. The last piece of REDLINE is actual visual images of the constructed activity captured in a digital format and linked to the same task activity. This is similar in concept to Liu’s multi-media construction daily log (M-LOG). (Liu, Stumpf, Chin, Ganeshan, Hicks, 1995)

REDLINE is intended to be recorded and compiled on a daily basis, visually recording activity starts, completion, interruptions, and delays. In conjunction with a computerized project schedule REDLINE becomes an excellent tool for establishing a visualization linking the “as built” schedule to the “as planned” schedule. This application became immediately apparent when reviewing REDLINE with the contractor. The issue of claims analysis involving delay and the concept that REDLINE can be reverse engineered to visually document an as-built project in direct comparison to an as-planned schedule assumed great importance to the contractors who viewed the model. This was not the original intent of developing the model but is a credible and to some parties a desirable tool for delay analysis and dispute resolution. Figure 2 shows an actual screen image of the project schedule with digital images of completed work linked to a specific activity. The activity underground plumbing was video taped with a date stamp imprint, then electronically captured and redlined with a paint application before being inserted in Microsoft Project and linked to the desired activity.

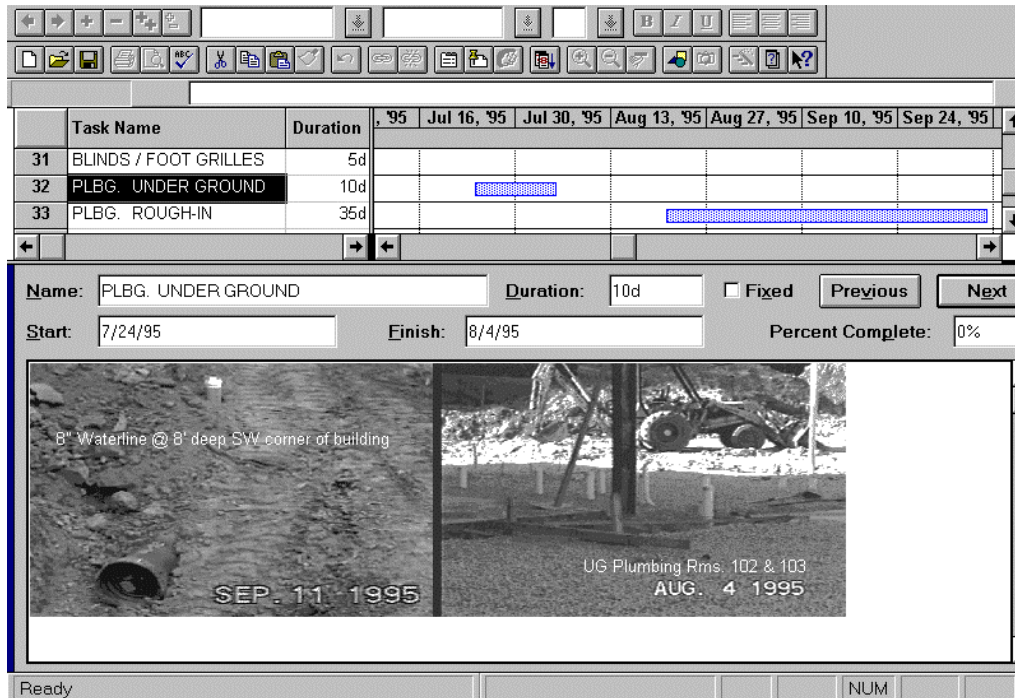


Figure 2. Linked activity

## REDLINE Implementation

REDLINE was developed using a regional project as the vehicle for implementation. This project was a major expansion and renovation to an existing facility. It was chosen for convenience and access. The standard construction document package is a typical mix of part CADD, and part manual drawings. The goal of REDLINE was to provide accurate, effective and useful as-built information in a real-time archival environment. The utilization and linking of graphical (contract drawings), images (low cost portable video capture) and retrievable data (Microsoft Project) appears to have reached this goal.

The required project schedule was prepared in Microsoft Project 4.0 for Windows by the contractor's project manager. MS Project is the typical scheduling software used by this and other contractor's on much of their work. REDLINE uses a common 486 Windows based computer for operation, manipulation and file storage. A Sony Hi-8mm, 10x-zoom camcorder was used to record as-built conditions and to record manual drawings for digitizing and capture. The procedure of video taping manual drawn blue-line reproductions produced a poor quality reproduction and has not been included in this paper. Manual drawings can be photographically reproduced at minimal cost and then digitally captured as a scanned document by the use of a video copystand. The scheduling software and the camcorder were standard tools used by the contractor during his field operations. A low cost (\$180) portable video capture device known as "Snappy" by Play Incorporated was used to capture video snapshots of both as-built conditions and non-CADD drawings for creating the electronic as-built drawings. One additional piece of software Paintshop Pro was used to enhance poorly captured video that was linked to the as-built drawing.

Each discrete work activity is identified by the project manager and loaded into the schedule. Associated activities are identified and then video taped using the camcorder with a date stamp visible on the image. Once taped the video camera is connected to “Snappy” using a standard RCA patch cable, and “Snappy” is connected to the computer through the computer’s standard parallel port. The “Snappy” software is opened and a video image is previewed on the computer screen. Once an appropriate image is visible it is captured and saved in a format compatible with MS Project. Both the Windows clipboard and MS Project accept standard .bmp files.

After capture, the images are stored in .bmp format. This prevents degradation that occurs in transforming a stored .jpg file to a usable .bmp file. The principles of object embedding are similar to other Windows based applications. To embed a visual as-built image into the archival project schedule is relatively simple. MS Project is opened to the Gantt Chart window with a split screen also opened to Task Forms, with a link to Details/Objects. The images are then inserted from their file storage location through the Insert/Object routine. (Lowery, 1994)

MS Project only accepts objects in vertical sequence on the Task Form. To utilize the horizontal format shown in Figures 2 and 3 requires image manipulation by joining multiple images as one object prior to using the Insert/Object command. REDLINE used Paintshop Pro as a file manipulator for enhancements prior to embedding the “as-built” image. Once the images are ready for archiving they are then REDLINED with pertinent field information to provide future records. This information can consist of room locations, horizontal and vertical control information, concealed utility information, column locations or other notations linked to the construction and the construction drawings. Additional information particularly tape counter references can be added to the REDLINED image for later retrieval. Once electronic embedding is achieved access to the documentation is available by accessing the schedule and clicking on an activity and its associated image. The drawing sheet and/or visual image can be globally linked to the activity and its parent application, through Windows object linking and embedding (OLE) routine. This allows subsequent updates to the “as-built” with several clicks of the mouse, followed by an editing session then re-saving the document. Once saved the “as-built” is automatically updated in the master “as-built” schedule. Upon completion of the project, the “as-built” path can be archived on inexpensive optical media by downloading the schedule to a read only CD-ROM.

### **Challenges**

The process of embedding is simple enough. The challenges are many but are surpassed by the benefits achieved by those involved in the process. Hardware and software compatibility are of a minor nature. Though a difficult challenge and minor inconvenience during the short term, these issues will ultimately be resolved. Snappy is able to handle image capture and storage under one of several graphical image standards including .bmp, .jpg, .gif. (Snappy Manual, 1994) Due to its compressible format .jpg is the preferred method of capture and archiving but at present neither the Windows clipboard nor MS Project supports the .jpg file format. An alternative strategy for “as-built” archives is the investigation of an indexing database that can handle graphics, CADD, and thumbnail imagery. For “as-built” archival purposes schedule linking is not necessary. In instances when claims may be an issue this application of tying activity start and finish dates to



visual images that can easily be recalled has great potential. Some form of program structure similar to REDLINE that links activity to drawing to image to field modification will ultimately be developed. The necessity for CADD imagery becomes readily apparent when trying to capture a usable “digital snapshot” of a blueline drawing. To be successfully implemented on a business as usual basis, REDLINE requires original digital drawings as a base with which to construct the “as-built.” Other methods of capture such as digital cameras are being explored. (Liu, Stumpf, Chin, Ganeshan, Hicks, 1995)

Storage capacity did not present any problems. The manipulation of the image prior to archiving allowed the image to be reduced in file size through the elimination of unnecessary colors. The images in Figure 3 originally captured in 16 million colors were reduced to 16 colors with a corresponding ten-fold reduction in file size. (See Figure 3) A sixteen million-color image is not needed. A black and white background image is a better image choice for record drawings. This can be followed up with color added to depict deviations. In implementing a process like REDLINE, a defacto standard for as-built documentation becomes the challenge.

Toward this goal the CII (Construction Industry Institute) has initiated two threads of involvement that the A/E/C industry/profession is involving itself. CII’s strategy for “Achieving an Integrated Data Environment” is through concepts of “integrated database” and the development of “electronic data interchange.” (CII #20-3, 1993) The biggest barrier to implementation of this organizational change is from the industry itself. The A/E/C industry is a slowly changing culture that must learn to extend beyond a separate discipline. The life-cycle of information, and decision-making coupled with before and after construction user activity means that the design professional's drawings will be doing far more duty then previously observed.

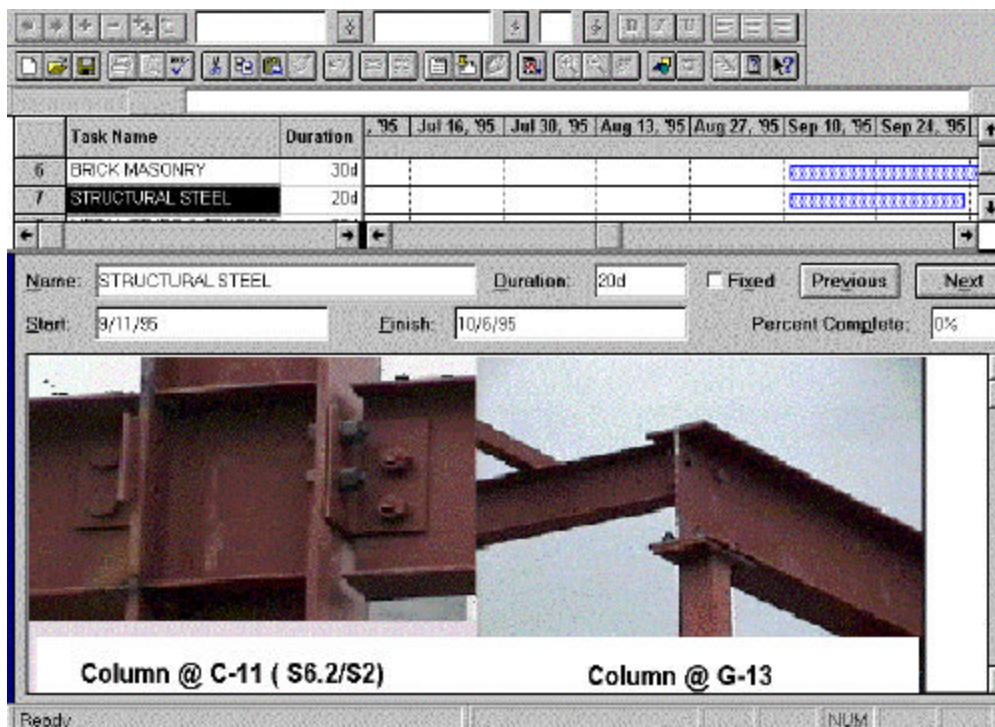


Figure 3. Sixteen color image

In creating an integrated database of standardized “as-built” documentation a cultural shift in organizational structure must occur. This cultural shift directed toward an integrated design construct profession must address issues regarding field implementation for data collection, disciplined life-cycle recording of data, purpose of recording the data, and developing drawings in electronic format. To accurately implement REDLINE the drawing package must be completed in a digital format and be provided as backgrounds for “record drawings.” Working from an electronic base sheet allows instant archiving, ease of manipulation, and quick retrieval, from which each participant in the design/construct profession benefits.

### **Conclusion**

REDLINE a viable process that is being implemented into the design and construction industry. This is being done with electronic object attachment to project schedules or as a database linked to specific project activities or actions. Future areas of investigation opened by implementing REDLINE concern field personnel implementation, contractual relations in preparing “as-builts,” and the multiple uses of electronic design drawings. As roles change in providing quality client services, these issues are creating new areas of exploration at each stage of the building life cycle. The future of “as-built” drawing documentation is a system of reusable base drawings, linked to a visual image electronically archived and easily retrievable. Which entity, owner, contractor, designer initiates the process and which entity demands implementation is still unknown. What is known, is that electronic as-built documentation is a proven process that is valuable in creating a building record.

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