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The HEC NexGen Software Development Project

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14. ABSTRACT
The NexGen project, a five-year project begun in 1990, is developing successor software packages to the existing family of HEC hydrologic engineering computer programs. The project is being accomplished through a management process that employs teams comprised of technical specialists, computer scientists, and consultants. Modern software engineering methods of requirements analysis, prototype development, field-testing, and feedback, are employed. Object-oriented program architecture implemented with C++ and advanced data features of FORTRAN90 are being used. Prototype models of NexGen software packages in catchment and river analysis are now operational and beta-test versions will be completed at the end of this next year. Final packages are expected to be completed on schedule. The package will be functional for RISC-chip and Intel-chip based desktop computers.

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The HEC NexGen Software Development Project[1]

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SUMMARY

The NexGen project, a five year project begun in 1990, is developing successor software packages to the existing family of HEC hydrologic engineering computer programs. The project is being accomplished through a management process that employs teams comprised of technical specialists, computer scientists, and consultants. Modern software engineering methods of requirements analysis, prototype development, field-testing, and feedback, are employed. Object-oriented program architecture implemented with C++ and advanced data features of FORTRAN 90 are being used. Prototype models of NexGen software packages in catchment and river analysis are now operational and beta-test versions will be completed at the end of this next year. Final packages are expected to be completed on schedule. The packages will be functional for RISC-chip and Intel-chip based desktop computers.

1. INTRODUCTION

The existing family of HEC programs is the culmination of 25 years of program development activities. The programs are operational in a batch mode on mainframe and minicomputers. For personal computers, they are assembled into packages comprised of one or more applications programs, supporting utilities, and a shell menu system for user interface. The programs are advanced in terms of computation and display capabilities. The structure of the programs, their interaction with the computation environment, and their essential functioning remains batch. The programs are powerful, technical state-the-art software products. They will be supported for the near-term, essentially as presently released.

The engineering applications computing environment is rapidly becoming that of the desktop computer, either high-end personal computers or engineering workstations. The engineer-user expects software that is state-of-the-art in technical capability, highly interactive, supported by high quality graphics, and controlled via a graphical user interface. Because of their evolution, the HEC programs are not well structured for efficient adaptation to this new environment. Also, the need to continually improve program capabilities makes it desirable to have computer code that can be easily modified and maintained.

A project, coined NexGen, was formulated to respond to these needs; that is, develop successor generation software to the present family of HEC programs. The project began in 1990 and is scheduled for completion in 1995. This paper describes the evolution and status of the HEC family of programs, the objectives and management approach for NexGen, findings and status of the project to date, and description of prototype models in river hydraulics and catchment analysis.

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2. FAMILY OF HEC PROGRAMS

The present computer program library, documentation, and support activities are the cumulative result of three eras of HEC activities. The first decade (1964 -1973) was that of single purpose programs, limited types and numbers of mainframe computer systems, and direct engineer to program user support activities. The second decade (1974 -1983) was that of packaged programs, integration of data management systems, improved graphics, mini- and mainframe computers and an expanded user community. The 1984 - 1993 decade is that of the personal computer characterized by a greatly expanded user community, increased attention to user interface and graphics, and diffused program distribution and support. Table 1 is a summary of the existing software library.

Program Category	Major Programs	Other Programs	Editors/ Utilities	Total Programs	Implemented for PC's
Surface Water Hydrology	4	6	-	10	4
River Hydraulics	3	4	6	13	11
Reservoirs	1	5	4	10	5
Statistical Hydrology	1	4	-	5	3
Planning Analysis	3	6	2	11	9
Water Quality	2	4	1	7	4
Data Storage System	3	0	13	16	10
Water Control	2	2	11	15	-
Miscellaneous	2	0	2	4	2
Totals	21	31	39	91	48

Table 1 Hydrologic Engineering Center Software Library

3. NexGen PROJECT OBJECTIVES, TEAMS, AND MANAGEMENT

Begun in October 1990, the HEC-wide project is now in the third year of work. The first year was devoted to forming project teams, investigating the array of software engineering issues, and documenting the technical requirements of the software packages. Technical teams were formed and charged with developing preliminary requirements statements for the areas of catchment analysis, river analysis, reservoir analysis, and flood damage analysis. Software support teams were similarly formed and charged with developing preliminary concepts for the areas of program architecture and design, graphical user interface, data base support, graphics, and program development environment and standards.

The teams were each headed by a senior HEC engineer or division chief and were comprised of 3 to 5 technical staff. Some staff served on two teams and all 25 HEC technical staff served on at least one team. Staff participated in team activities on a part-time basis while continuing to perform their regular duties. The teams developed consensus on their respective assignments, developed plans for their accomplishment, and provided a study report of findings. The team leader provided direction, called meetings, recorded findings, provided for coordination with other teams, and performed briefings for HEC division chiefs and director. Project files were maintained on matters related to team activities with minutes recorded for meetings convened. The teams were encouraged to seek Center-wide participation in forming ideas and developing products through seminars and other forums and circulation of concept papers. The teams also brought in speakers and consultants with specialized knowledge from outside the Corps.

Team leaders reported to their respective division chief on NexGen project matters. Team leader duties were considered a normal assignment subject to common supervision and performance appraisal. Direct contact and work with team members throughout HEC was encouraged. Management oversight was provided through an executive committee comprised of the team leaders and chaired by the director. The oversight committee met monthly to monitor progress ensures coordination, and surface for resolution common issues that might impede progress.

4. TEAM FINDINGS

The technical teams confirmed the NexGen goal of developing a family of hydrologic engineering software packages to serve the U. S. Army Corps of Engineers into the next century. The packages will be integrated and be designed for interactive use in a multi-tasking, multi-user network environment. The catchment and river analysis software packages were designated for accelerated prototype development. The findings and recommendations of the software support and technical teams are described below.

4.1 Program Architecture, Design, User Interface, and Development Environment

These three teams addressed the issues of computation environment, program architecture, coding language relationship to architecture, software engineering related to program design, and computer hardware and software industry standards. Specific items studied included: present and emerging desktop machines, concept of object-oriented design and programming [1], UNIX [2], X Windows [3], C [4] and C++ [5], Motif [6], FORTRAN 90 [7], and Microsoft Windows [8].

The teams concluded that development should target both RISC-chip based engineering workstations running standard AT&T UNIX [9], and high-end Intel-chip MS-DOS [10] based personal computers running in a window environment. Programs should be developed for use through a graphical user interface (GUI). In UNIX, development should follow the X Windows standard using Motif for the GUI. In MS-DOS, Microsoft Windows should be the development environment, with later consideration of Windows NT [11]. Object-oriented programming (OOP) concepts employing C++ and advanced features of FORTRAN 90 were recommended for consideration for program coding. Program architecture, consistent with the above, was formulated and recommended for testing. Figure 1 is a diagram of the recommended NexGen software architecture. Note the deliberate separation of the GUI, graphics, compute engine, and date base in the program architecture.

4.2 Data Base Support

The team addressed the issue of providing for the data persistence necessary to support the GUI, graphics, and technical analysis envisioned for NexGen. Specific items investigated included time-series, paired-function, model-parameter, geometry, spatial, and image data needs; and available commercial systems and associated licenses, fees, and platform portability.

The team concluded that the HEC-DSS system [12] best meets the time-series and paired-function data management needs. Model-parameter, and geometry data management needs were concluded to be relatively modest compared to the capabilities of commercial systems. Therefore, the need for a commercial data base management system was discounted. The team recommended that a study be initiated that would investigate the feasibility and design of additional data conventions for HEC-DSS

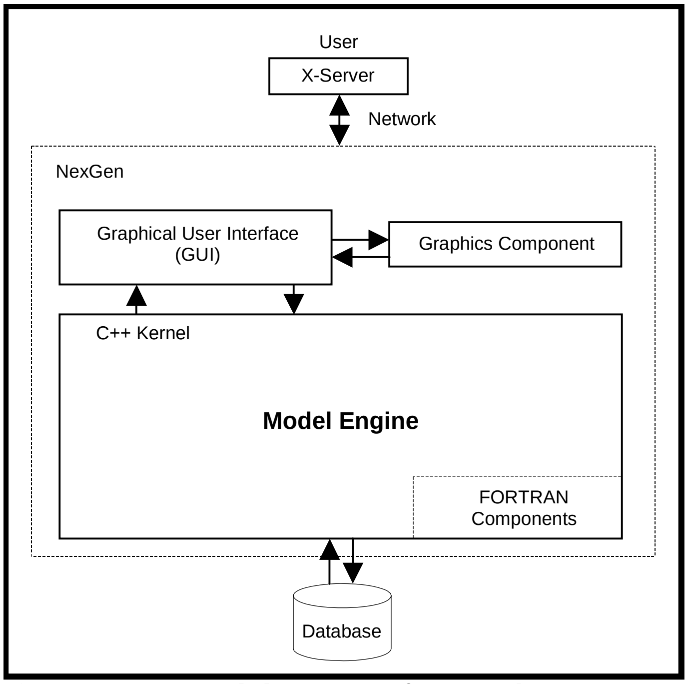

Figure 1 Recommended NexGen Software Architecture

that would enable it to also manage these data types. No firm conclusions were reached regarding spatial and image data management support for NexGen. The team recommended deferring decisions for these data types pending the outcome of other on-going work at HEC in geographic information systems. A key part of NexGen's contribution is working with data in its natural and logical format and not as concocted for input to the computer.

4.3 Graphics

The team addressed the issues of the nature and amount of data to display, types of displays, and approach to incorporate graphics into NexGen. Specific items investigated included on the fly versus exit/call concepts, commercial package capabilities, graphics standards, and compatibility of Windows and UNIX graphics.

The team concluded that graphics (often termed visualization) should follow published and de facto industry standards such as X Windows, and be targeted for common display and output devices. The team recommended use of high-level graphics packages rather that custom coding, and that coding be performed in a modular manner to enable changes to other platforms and graphics packages with minimum code re-write. The team recommended that the commercial package UNIRAS [13] be tested for the UNIX environment and Visual Basic [14] and Windows programming tools [15] be tested for the DOS environment.

4.4 River Analysis

The team recommended the River Analysis System as the successor to existing steady-flow - HEC-2 [12], unsteady-flow - UNET [12], and movable boundary - HEC-6 [12] programs. The team concluded that the package should comprise components that perform steady, unsteady, and movable boundary hydraulics using common geometry data, and common geometric and hydraulic computation routines. A

GUI will be developed for data entry, execution control, and graphic display. Capabilities of existing software packages are to be carried forward and new state-of-the art algorithms added. For the steady-flow component, complete re-coding in FORTRAN 90 was recommended and is underway, and algorithms for single execution subcritical and supercritical profile computation have been developed. The existing bridge analysis will be reformulated into a single bridge representation with automated determination of appropriate analysis method. The team recommended that development of a prototype of the steady-flow component be undertaken first. The team also recommended a study be made of the desirability of adding cross-sectional geometry data management to HEC-DSS.

For the unsteady-flow component, the culvert and bridge routines developed for the steady-flow component would be incorporated. Additional graphic editing and display capability will be incorporated. Similar improvements for the mobile boundary component are planned. The possibility of adapting the mobile boundary component to event analysis, in lieu of the present analysis using a representative flow-duration relationship, was recommended for study.

4.5 Catchment Analysis

The team recommended that the Catchment Analysis System be developed as the successor to the existing flood hydrograph package - HEC-1 [12], and the several other hydrograph analysis related special purpose programs in the HEC software library. The team concluded that initially, the catchment system should be an event analysis tool but that it should be designed and developed for later extension to continuous simulation analysis. Capabilities of existing software packages, where appropriate, would be carried forward, with modest technical improvements made. Capability to perform event analysis from spatially varying precipitation patterns will be developed. New generation radar with such capability is expected to soon become available [16]. The team recommended that a catchment analysis system prototype be developed using object-oriented design and programming.

4.6 Reservoir System and Flood Damage Analysis

These teams recommended that software packages currently under development be continued as presently planned, thus deferring full NexGen related focus for a year. In the reservoir area, development of the prescriptive reservoir model - HEC-PRM [17], was recommended for accelerated completion. It is now planned for release in early 1993. Later, need for improved low-flow simulation analysis and a dedicated, real-time flood control release model would be addressed. In the flood damage area, accelerated completion of the near real-time project benefits accomplishments package - HEC-PBA [18] was recommended. Requirements analysis studies of adapting to NexGen concepts of GUI's, integrated graphics, and relatively seamless integration with other NexGen software packages would be undertaken at a later date.

5. PROTOTYPE SOFTWARE PACKAGES

A development team reporting directly to the HEC director was formed to work exclusively on the project during the second year to focus attention on critical decision items and produce an early stage working prototype. The team consisted of a senior HEC manager, hydraulic engineer, computer system analyst, and software development consultant. The team was assigned the task of developing a functioning catchment model prototype implementing the recommendations of the several software support teams.

The completed prototype performs precipitation, infiltration, runoff transform, routing, and network catchment modeling. The prototype was designed and developed following object-oriented principles. The basic program kernel and a few simple computation routines are coded in C++; coding for most computations and database operations (HEC-DSS) come from existing FORTRAN routines. A commercial package - UIM/X [19] was used to develop the GUI. UIM/X generates C code. The UNIRAS commercial graphics package is being evaluated for the display capability.

Figure 2 is a mosaic of display screens that might occur during a session with the prototype catchment model. The number of windows simultaneously open during a session is limited only by the size and resolution of the display monitor. The session might begin by calling up the program and retrieving a partially complete data set for the Allegheny basin. Positioning additional model palette

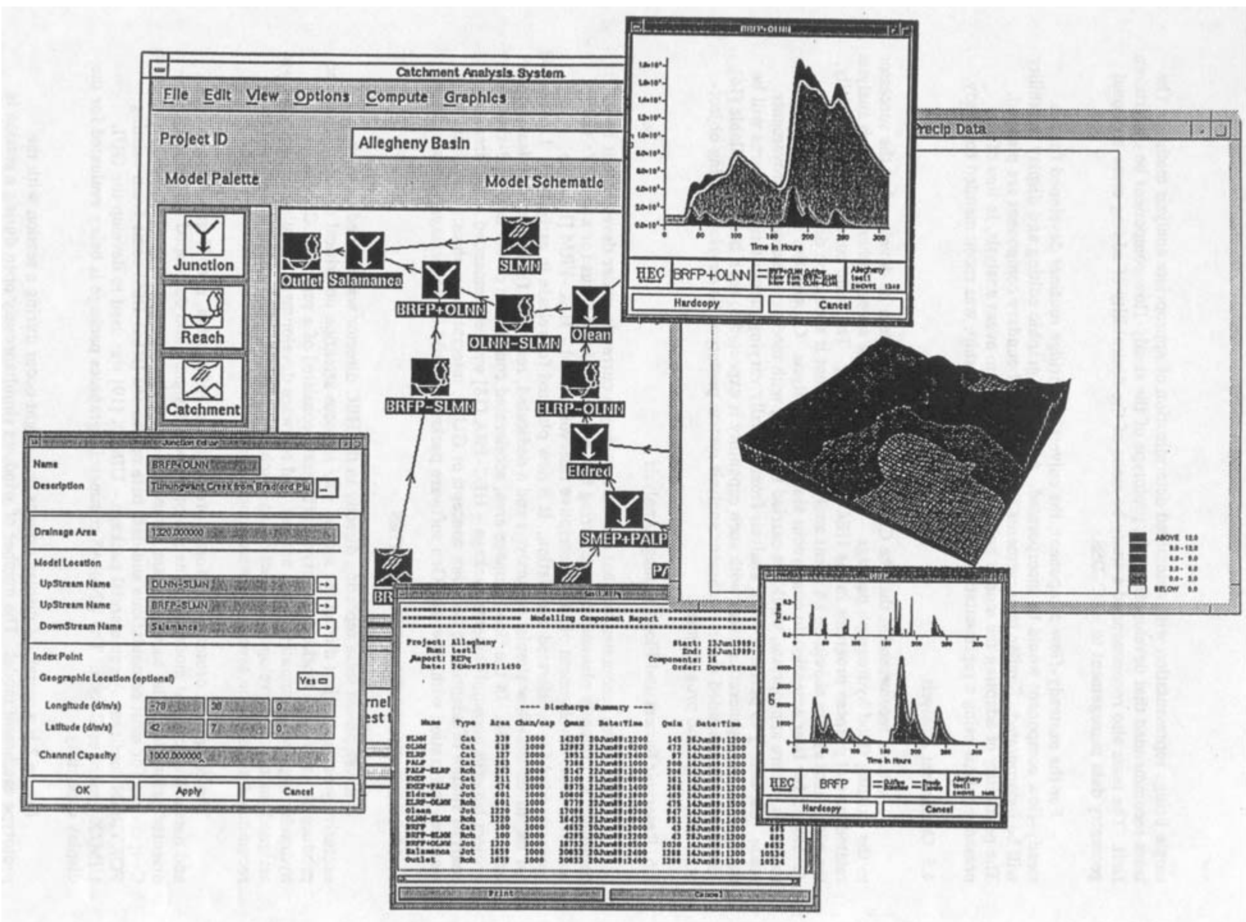

Figure 2 Display Screen from Catchment Model Prototype Session

items on the schematic expands basin configuration. This is accomplished with click and drag mouse operations. Windows for the junction, reach, and catchment editors are opened and data entered or edited. The model may then be executed and text and graphic output for selected locations displayed. Comparison of runoff at several locations might also be graphically requested (via point and click operations) and displayed. The session might then continue with further editing, model configuration modifications, and executions.

In a complementary effort, the river analysis team developed a prototype model designed for Intel-DOS machines running under Microsoft Windows. Visual Basic is used to develop the GUI and some graphics and Windows programming tools are used for the graphics, display, and hard copy capability. New geometry and hydraulic properties, and steady-flow step backwater subcritical and supercritical routines were developed for the prototype model. The code is new and takes advantage of advanced data structures available in FORTRAN 90.

Figure 3 displays a screen that might occur during a session with the prototype river analysis model. The session might begin by calling up the program and retrieving an existing data set for the Red Fox river. Cross-sectional geometry, hydraulic roughness, and reach lengths for Reach 1; river mile .03 is edited to reflect recently acquired field data. A plot of the edited cross-section, requested through point and click mouse operations, is displayed to permit viewing the edited data. A culvert is added to the reach by selecting the appropriate item from the feature palette and inserting it into the reach schematic at the desired location. This is accomplished through click and drag mouse operations. The model is then executed and a profile plot requested and displayed. The computed profile indicates that a hydraulic jump will occur near the transition from steep to mild slope. Further editing and model executions might then be performed to test the profile sensitivity to model parameter values. Various profile plots could be superposed to assist in studying the results.

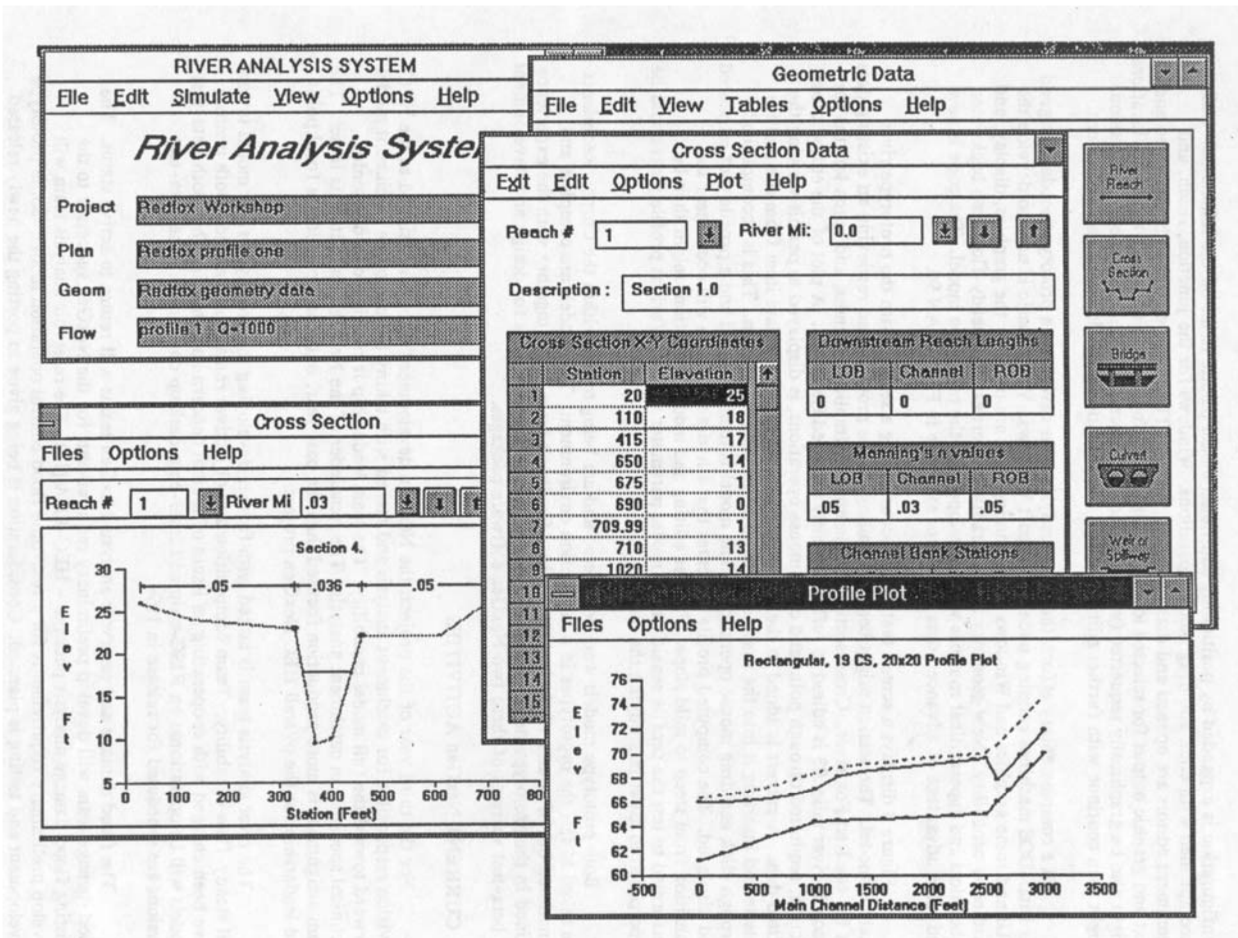

Figure 3 Display Screen from River Model Prototype Session

Both prototype models were completed and are being tested within the Corps. Recipients are asked to test the prototypes in a production environment. The models are complete and functional but of course of limited capability. Feedback from users, together with the experience gained in the prototype development efforts, will provide a firm basis for design and development of beta-test versions of these two NexGen software packages.

6. CURRENT NexGen ACTIVITIES

For the third year of the project, the NexGen development team is reassigned to the HEC division responsible for catchment analysis and tasked with taking the prototype catchment model forward toward the full model capability. The team leadership is reassigned to our senior technical specialist in catchment analysis. The remainder of the NexGen team staff is intact. The team assignment is more production focused than the past year, but it still provides a focal point and leadership for the overall HEC NexGen project.

The river analysis team is tasked with further developing the prototype river model toward full steady-flow capability. Team composition and objectives remain unchanged. Both teams have been charged with cooperating on issues of mutual concern and ensuring that both beta-test models will be operational on RISC-chip and Intel-chip desktop computers. The beta-test versions are scheduled for release in 1994

The flood damage and reservoir analysis NexGen teams will return to active status. The flood damage team will develop preliminary requirements for the NexGen successor to the existing flood damage analysis package - HEC-FDA [12]. The reservoir analysis team will develop preliminary requirements for a real-time flood control operation model. Some prototype development and testing is planned. Consideration is being given to porting the newly released prescriptive reservoir programs (HEC-PRM) and interior flooding hydrology program - HEC-IFH [12] to the NexGen environment. The graphics and data teams may be reactivated to serve in an advisory capacity. Team memberships are adjusted to reflect the past years accomplishments and changes in staff locations and assignments.

7. CONCLUSIONS

The NexGen project will develop successor generation software packages for the engineering community of the U.S. Army Corps of Engineers. Concepts of object-oriented software design and development offer significant potential benefit in NexGen software development. Adherence to published hardware and software standards where available, and de facto standards otherwise, is critical to NexGen success. Developing prototype catchment and river analysis models proved to be essential to surfacing and resolving critical technical and software engineering issues. A structured management approach which employs investigative and development teams is being successfully followed. The NexGen project is expected to be completed on schedule in 1995.

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