COMPUTER SCIENCES CORPORATION

MEMORANDUM

April 20, 1964

TO: Don Breheim, International Business Machines Corporation

FROM: Bob Paul, Computer Sciences Corporation

SUBJECT: Impact of Changes to 7095 FORTRAN IV Language Specifications

REFERENCE: "Objectives and Definition of a Programming System for the IBM
7095 Computer and a Proposal for item Implementation," dated
October 22, 1963

INTRODUCTION

The purpose of this memorandum is to state the impact of the recent IBM directive
relating to the 7095 FORTRAN IV system design.

BACKGROUND

Since November 1963, when work began on the 7095 FORTRAN IV compiler design,
CSC has been directed to produce a compiler which would represent a significant
advance in compiling performance, and through the introduction of various new opti-
mization techniques, to produce a highly efficient object code.

In order to achieve the required optimization it is necessary to introduce extensions
to the language. In an attempt to introduce as many optimization features as possible,
a few minor language extensions were introduced. In addition, a few other language
extensions were introduced to enrich the language and relax some of the programming
restrictions. These extensions were all specifically stated in the above referenced
proposal and are referred to the statement of work dated March 25, 1964 and mutually
accepted by IBM and CSC on April 6, 1963. The following is the list of the subject
language extensions extracted from the referenced proposal.

"Language Extensions

Following is a summary of FORTRAN Language extensions . . . .

A PARAMETER statement will be added to permit easy modification
of variables which provide improved optimization when fixed at
compiler time.

DIMENSION statement rules will be relaxed. Type statements may
contain dimensionality; any number of dimensions may be used, and
expressions may be used to state dimensions.

Mixed arithmetic expressions will be permitted. (Rules defining
arithmetic expressions and mixed usage are included in Appendix B.)

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Statement labels may be subroutine arguments.

RETURN may specify an exit other than normal.

Optional end-of-file exits will be provided for input statements.

Subscripting restrictions in statement functions will be relaxed.

Expressions may be used more freely. Specifically, they may be placed in subscripts, limits of a DO, computed GO TO statements, output statements, and dimension limits.

An ABNORMAL statement will be provided to enable designation of functions which should not be subject to ordinary optimization rules.

The EXTERNAL statement will be extended to allow specification of the number and modes of SUBROUTINE and FUNCTION arguments, thereby enabling the compiler to take appropriate corrective or diagnostic action. "

On 10 March 1964, CSC was directed to conduct a detail study into the FORTRAN IV language in an attempt to extend it. The specific instructions were to introduce any language extensions that were necessary to provide the maximum amount of power and utility to the source programmer. After some work was performed on the design of these extensions, CSC was directed to stop current work and to prepare a report summarizing the work that had been done to date. A report of these proposed extensions was submitted to IBM on 3 April 1964 and all work discontinued.

On 27 March 1964, CSC received from IBM a copy of the "Statement of Work, " dated 25 March 1964 which represented a redraft of a copy of a work statement which was submitted to IBM with additional information clarifying the scope of work and better defining the specific documents to be supplied at the conclusion of the system design effort. The document was considered generally acceptable to IBM. On 6 April 1964, CSC and IBM mutually agreed on the Statement of Work, with the exception of further clarification of the IBSYS Modifications effort.

RE-DIRECTION

On 13 April 1964, CSC received a memorandum which stated that the language modifications and additions described in the above mentioned proposal "are no longer to be considered in the design of the 7095 FORTRAN IV compiler; the required specifications for the 7095 are described in the 'IBM 7090/7094 FORTRAN IV Language' documents, C28-6824-2, C28-6376, and C28-6377."

This memorandum details the impact upon the 7095 Project of this re-direction.

IMPACT OF RE-DIRECTION

Change in Compiler Utility and Performance

The liberalization of usage incorporated in the proposed design removes some of the severely criticized inadequacies of FORTRAN IV, and significantly extends the power of the language. Consequently, its utility will be enhanced.

Specifically:

The removal of the PARAMETER statement is analogous to the removal of EQU from the assembly language, i.e., reparameterization of source programs could in many cases become a time-consuming process whereas with this statement this task is perfunctory.

Removal of the ABNORMAL statement precludes the generation of optimum code in some instances and precludes the generation of correct code (such as optimization of expressions involving abnormal variables) in other cases. Further regression in design to avoid the latter case would result in very significant degradation of object program performance.

The removal of mixed arithmetic expressions causes extraneous code to be generated in the object program and also results in a more awkwardly written source program, thereby decreasing the efficiency of the resulting object code.

Removal of the ability to write expressions in subscripts precludes certain optimizations. The remaining language extensions also appear in the 7094 FORTRAN IV Language or were added to provide utility to the source programmer.

Change in Schedule

The FORTRAN Level 1 Internal Documentation Review is changed from 15 April 1964 to 7 May 1964. The FORTRAN Level 2 Internal Documentation Review is changed from 1 July 1964 to 1 August 1964. The availability for delivery of the FORTRAN IV Internal Design Manual is changed from 1 August 1964 to 1 September 1964. The Preliminary review of the FORTRAN IV Reference Manual is changed from 15 April 1964 to 1 June 1964. The final review of the FORTRAN IV Reference Manual is changed from 1 July 1964 to 1 August 1964. The availability of the published FORTRAN IV Reference Manual is changed from 1 August 1964 to 1 September 1964.

Change in Manpower

One (1) additional man will be needed, effective immediately.

Change in Compiler Design

The elimination of the proposed extensions to the FORTRAN IV Language for the 7095 compiler will require a complete redesign of Phase I; the original design of Phase I was shaped generally by the presumed availability of these language

extensions, which, in turn, allowed the relaxation of the restrictions on the appearance of the general expression form, and on the mixing of modes. To achieve comparably efficient processing of the object program while complying with current re-direction, the general processing approach of Phase I must be changed substantially. The remaining phases of the compiler will only be slightly affected by the elimination of these proposed extensions.

7095 FORTRAN INCOMPATIBILITIES

The following optimizations, extracted from the above mentioned proposal, will be performed:

Redundant recomputations of expressions over an entire program will be eliminated from subscript and arithmetic quantities.

Non-loop dependent subexpressions will be removed from loops.*

Nests of loops which can be written in fewer loops will usually be collapsed.

Indexing analysis will be performed in order to reduce the amount of computation needed to form indexing quantities, reduce the amount of loading and storing of indexing quantities, and eliminate materialization of the induction variable wherever practical.

In subprograms, references to non-dimensioned dummy arguments which are not defined in the subprogram will be made to the argument values which are fetched by the prologue code.

Some terms (arithmetic as well as subscript) which contain induction variables will be incremented instead of being recomputed each time through a loop.

The contents of the accumulator and MQ will be remembered cross-statements.

Special cases of certain sequences for which better code may be produced will be recognized.

Compile time conversions of constants from one mode to another will be accomplished wherever indicated . . .

Computations of subexpressions which may be evaluated at compile time will be performed . . ."

As a result of some of these optimizations, and imprecise language definition, certain minor incompatibilities between 7090/94 FORTRAN IV and the 7095 FORTRAN IV (as redirected) exist. Though these incompatibilities are theoretically possible, it should be kept in mind that they will occur only in very remote cases. In addition,

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*The analysis of common subexpressions will make the assumption that the EQUIVALENCE statement is not used to define mathematical equivalence. This decision can be easily reversed or a new statement could be provided to indicate possible mathematical equivalence between variables.

it is primarily a result of differences in implementation technique that they can occur at all.

CSC was requested to submit a list of these incompatibilities. The following list is submitted for your review; if no response has been received concerning these points by 1 May 1964, it will be assumed that they meet with IBM's approval:

1. The different ordering of computations may yield different results. (No violation of FORTRAN rules.)

2. The elimination of certain computations, and the moving of certain computations when they are found to be common subexpressions, may yield incompatible results in the following cases.

    a. The setting of computer triggers (overflow, divide, check, etc.) may be altered when the computations of expressions are moved or eliminated.

    b. If variables are being changed asynchronously by simultaneous input/output, expressions involving those variables may be computed with outdated values of the variable. It should be noted here that asynchronous modification of any variables is not included as an explicit FORTRAN capability.

    c. If expressions in subprograms contain references to dummy arguments whose calling parameter appears in COMMON, these expressions may be computed with outdated values of the variables.

    d. If a variable appears in the call to a subprogram as a replacement for more than one dummy argument, expressions involving those dummy arguments may be computed with outdated values.

Note: The conditions mentioned in each of the cases are true of the current 7090-7094 FORTRAN with regard to subscript expressions, since it will eliminate common subexpressions in subscripts. These conditions will arise in the 7095 FORTRAN for arithmetic expressions as well as subscripting expressions, since we are eliminating both common arithmetic subexpressions and subscripting expressions.

3. The induction variable may not always be materialized in the same places as was done in 7094 FORTRAN IV.

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