VIII

JOVIAL Session

Chairman: John Goodenough
Speaker: Jules I. Schwartz

PAPER: THE DEVELOPMENT OF JOVIAL

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1. The Background

1.1. The Environmental and Personnel Setting

The time was late 1958. Computers that those who were involved with the first JOVIAL project had been using included the JOHNNIAC (built at RAND Corporation), the IBM AN/FSQ-7 (for SAGE), 701, and 704. A few had worked with board wired calculators. Some had never programmed. For those using IBM, the 709 was the current machine. There were various other manufacturers at the time, some of whom do not exist today as computer manufacturers.

The vacuum tube was still in vogue. Very large memories, either high-speed direct access or peripheral storage, didn't exist, except for magnetic tape and drums on some computers.

The first large-scale system which was built and maintained by thousands of people was in the process of being installed after a considerable amount of effort, expense, and technological innovation. Called SAGE, it was a large real-time system (very large by 1958 standards). It had, among other things, an interesting and very valuable (even by today's standards) utility system for assisting in development. This included the Communication Pool. The Comm Pool's purpose was to permit the sharing of System Data among many programs by providing a centralized data description. Programming for SAGE had been done in machine language, as was almost all programming up to that time.

FORTRAN existed and had been in use for a few years, but use of higher level languages wasn't nearly as common as the use of such languages today. Certainly the majority of people involved in compiler efforts at that time, and in particular the initial JOVIAL language development and compiler effort, had almost no experience with such activities.

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I had had experience with the language and compiler called PACT (Project for Automatic Coding Techniques) which was developed and described in 1954–1955 (Melahn *et al.*, 1956). But actually this experience, largely because of the nature of that language and the computer the first version ran on (the IBM 701), was not particularly valuable for the development of languages in the ALGOL class.

One of the significant things that got the JOVIAL language and compiler work started was an article on Expression Analysis that appeared in the 1958 *Communications of the ACM* (Wolpe, 1958). The fact that this was actually quite a revelation to us at that time seems interesting now. Since that day, of course, there have been many developments in the parsing of mathematical and logical expressions. However, that article was the first exposure many of us had to the subject. Some of us who had just finished work on some other projects (including SAGE) began experimentation with the processing of complex expressions to produce an intermediate language utilizing the techniques described. There was no compiler language at the time in our plans, but the idea of being able to understand and parse complex expressions in itself was of sufficient interest to motivate our efforts.

Another article which was to have great influence on our future development was also published in the *Communications of the ACM* in 1958. This was the description of what was then called the International Algebraic Language (IAL, later called ALGOL), which had been defined by what became (and for the most part had been) an esteemed group of computer people (Perlis and Samelson, 1958).

1.2. The Economic and Situation Stimulus

JOVIAL really got its beginning because of the launching by the Air Force of another large system. This one followed SAGE and it was called the SACCS System. SACCS was to be developed from scratch. This meant new computers, a new system, new programming techniques, and a new operating (executive) system. All of these had to be developed before the operational program could be developed. The main computer was the IBM AN/FSQ-31. Other communications computers (built by ITT) were also utilized.

1.3. The Technical Base for JOVIAL

The two major influences on the language of JOVIAL were, first, the International Algebraic Language, which served as the language architectural base, and SAGE, which contributed to the knowledge of many of the problems and ideas needed to solve the large programming system problem. IAL was chosen as the base language for several reasons. One was that at the time it appeared as if it would become the commonly accepted standard for languages. Secondly, it seemed like a better technical basis for a new language than FORTRAN, which was the only other possibility. SAGE influenced such matters as data handling, Communication Pool, and the need for a variety of types of variables (items or elements). These things were deemed essential to the programming of SACCS and served as the basis for the first definition of JOVIAL.

1.4. Organizational and People Beginnings

The first actual contribution to the language effort that eventually led to JOVIAL was the small study which took place at SDC in California in the latter part of 1958. As stated before, it started with experimentation with the analysis of logical and mathematical expressions. And, although the intent was not, at the time, to start developing a language, that was not completely out of the realm of possibility. (But it should be remembered that up until then language development was not a wide-spread phenomenon. Within a year or two, it would become as wide-spread as certain viruses.) Key members of this study were Erwin Book, Harvey Bratman, and myself. During the latter months of 1958, I was transferred to New Jersey to work on the SACCS project. This transfer came shortly after the publication of the description of IAL in the *Communications of the ACM* that was referenced above. Based on the experience with SAGE and the reading of the IAL description, I recommended to the SACCS development managers, prior to my transfer, the use of a higher level language to program the system. To my and a number of other people's surprise, this recommendation was accepted.

Actually the final recommendation was made in New Jersey, where the SACCS program was to be developed. This written recommendation was done with a paper typed on about seven or eight onion-skin pages around December 1958. The title of it was "OVIAL—Our Version of the International Algebraic Language". It was a brief description of some of the language concepts which could be implemented in order to develop the SACCS program. This paper was accepted as the beginning of the project, and the first work was begun. (I realized some years later that I had not kept that paper. There were not many copies, and it was never a formally issued document. At the time it seemed like a relatively small item and not likely to be continued much in the future, at least outside of the particular SACCS development environment. So the paper didn't seem very important to me. Now it would be of great interest to me for several reasons. One is its historical interest to me and perhaps some others. Secondly, I am quite curious what my first ideas were at that time for the language I called OVIAL.)

The project that was formed to develop this language and compilers for it was called the CUSS (Compiler and Utility System for SACCS) project. It was part of the SACCS Division of System Development Corporation which at the time was serving as a subcontractor to IEC. IEC was part of the ITT complex, formed specifically to develop the SACCS system.

During this period of the organization and beginning of the JOVIAL effort in New Jersey, the other members of the team who did some of the initial language investigation also started a project to develop a language. Eventually this language was called CLIP (Compiler Language for Information Processing) (Bratman, 1959; Englund and Clark, 1961). These two activities, the one in New Jersey and the one in California, were rather independent efforts, the one in California being somewhat research oriented, while the one in New Jersey on JOVIAL was operationally oriented—and in fact with a fairly difficult schedule (which wasn't met).

The people on the CUSS project were primarily implementors. With the exception of my own experience with the language PACT in 1954 and 1955, nobody else on the project had any experience with compilers or languages. Some had had experience in the development of the SAGE system. For some members of the project, this was their first programming experience. The list of people who served at least sometime on the CUSS project (and their current, or last known affiliation, where known) follows:

Jules Schwartz	(Manager)
Moe Spierer	(Manager 709 JOVIAL)(CSC)
Hank Howell	(Manager Q-31 JOVIAL)(SDC)

Paul McIsaac	(Data Vantage)
John Rafferty	(IBM)
Patricia Weaver	(Unaffiliated)
Emmanuel Hayes	(Century Data Systems)
Lynn Shirley	(Consultant)
Jack Friedland	(Consultant)
Donna Neeb	(CSC)
Richard Brewer	(TELOS)
Stan Cohn	(Unknown)
Mike Denlinger	(Unknown)
John Bockhorst	(Northrop)
Phil Bartram	(Unknown)
Frank Palmer	(SDC)
Ed Foote	(IBM)
John Dolan	(Unknown)
Patricia Metz	(Unknown)

Some of the members of the CLIP Project, in addition to Book and Bratman mentioned previously, were:

Howard Manelowitz
Don Englund
Harold Isbitz
Ellen Clark
Ellis Myer

1.5. History of the Name

Since it has been stated that this paper on JOVIAL will serve as some sort of permanent record of the language, this seems like the right place to describe the origin of the name. For many people this seems to be the most important and best known part of the language. I have over the years met many people who know the name (and that Jules is part of it) but know nothing about the language. There is a discussion of this in Sammet's book on languages (Sammet, 1969), but the following expands somewhat on that.

As stated above, the name OVIAL was the one originally recommended, which meant Our Version of the International Algebraic Language. In the late 1950s, society wasn't quite as free thinking as it is today. The name OVIAL seemed to have a connotation relative to the birth process that did not seem acceptable to some people. So, during a meeting, held approximately January 1959, at which a number of technical issues were discussed—a meeting attended by members of the staff of the SACCS Division Management, the CUSS project, and IEC personnel—the subject of an acceptable name for the language was initiated. Someone in the group, and it's not known by me who it was, suggested the name JOVIAL. This seemed like the easiest transition from OVIAL. The question then was the meaning of the "J." Since I was standing in front of the room conducting the meeting at the time, somebody—perhaps somebody other than the one who suggested JOVIAL—suggested it be called Jules' Own Version of the International Algebraic Language. This suggestion was met with laughter by the assembled group. The meeting ended shortly afterward without actually finalizing the discussion of the name.

I left town for a trip soon after. Upon my return I found that the IEC people had put in the performance contract an obligation for SDC to develop the language called "JOVIAL (Jules' Own Version of the International Algebraic Language) and compilers for this language for the IBM 709 and AN/FSQ-31." The AN/FSQ-31 computer wasn't due to be installed for quite some time, but the 709 was available and was to be used by user personnel for a variety of kinds of work. (I didn't remember who the IEC people were, but was told in 1976 by Joe Ceran, now of CSC, who was then one of the IEC personnel at the meeting.) Thus, along with the dates for various deliveries, the name JOVIAL, which included my first name, became the official term.

1.6. Objectives

Both compilers were to be delivered to the Strategic Air Command in Omaha and to be used for a variety of functions. The AN/FSQ-31 Compiler was intended for the programming of the SACCS System, the 709 for a variety of other ongoing SAC functions as well as the early development of the Q-31 Development System prior to the availability of the Q-31. The JOVIAL language was to be the same for both the 709 and Q-31. The compilers were to be programmed in JOVIAL.

1.7. Schedules and Allocated Manpower

I have not been able to find the original contract statements containing the actual schedules that were required. Whatever they were, it is quite certain that they didn't get met. As I recall, the first version of the compiler for the language was scheduled something like six months after the beginning of the effort on the IBM 709. Since the AN/FSQ-31 wasn't due to be installed for quite some time afterwards, that had a much later scheduled delivery. The number of people on the project soon after it got started was around nine and it grew to a maximum of about 15 people as the CUSS project continued. The actual first users of JOVIAL, aside from the compiler developers themselves, were to use the first processor, which was an interpreter, not a compiler, for a very simple subset of the language, which was available in about 12 months (around January 1960).

People within the SACCS development effort began to use the language for very simple things (e.g., short subroutines for conversion, calculations, expression analysis). There were somewhere around eight man-years' effort before the language began to be used. About 25 man-years of effort were expended before very heavy use of the 709 Compiler took place. The first programs to make use of the compilers (outside of the compiler builders) were the utility and executive systems that were to be used for the further development of the SACCS system. The compiler development itself utilized the early compilers. Once the earliest subset of the language was available in a machine-coded compiler, the compiler was immediately reprogrammed in that language. From then on, all versions were programmed in some version of JOVIAL.

1.8. Planning and Procedures

Today there are a variety of concepts for orderly development, including structured programming, structured design, top-down development, continuously evolving specifications, and in general rigorous planning and disciplined effort. These ideas were unknown to the original JOVIAL development. The language design actually proceeded largely in parallel with the implementation of the compilers. There were some basic concepts (e.g., IAL, SAGE data definitions) and enough definition to get started with the development, but a firm baseline never existed, and changes were made almost daily. The early documents were limited and essentially working papers, subject to considerable change. No reasonably complete "final" documents were published until the end of the major work.

The main "management technique" used was frequent interaction among all personnel, including the project leaders, where changes, techniques, and progress were discussed on an individual and group basis. Although not to be recommended as the major way to run a project, it seemed to work for this project (where most personnel, although rather inexperienced, were quite capable and hard-working). No detailed plans or schedules or systematic growth from design through testing were ever written or followed. The only real test case was the compiler itself.

The first official document on JOVIAL was published in April 1959 (Schwartz, 1959a) and the second in May 1959 (Schwartz, 1959b). These described a number of the concepts and details of the language. Additional documents came out on the state of the language over the next six months.

Since one of the major emphases of this language was to be the development of the compiler in the language itself, many of the ideas for the language came from those who were actually in the process of developing parts of the compiler. Changes were suggested by those people as they programmed.

Many of the important parts of the language were developed in an incredibly short time. A good example of this is the Data Definition Capability, which was the original heart of JOVIAL. It was not well defined when we embarked on the development effort. It had to be developed as the compiler development proceeded. When it was determined that we couldn't postpone the data definition any longer, it was developed in about 30 minutes. One other person (H. Howell) and I examined each possible type and structure and developed the syntax for them immediately (Howell, 1960). Those who know the original JOVIAL will readily agree that that part of the language could have been developed in only 30 minutes. Many of the syntactic improvements over the years have been in that area, although the capability provided has always been well received. Other language features (such as the CLOSE Routine and Item Switch—discussed below) were decided on and added in minutes. Rarely did language features require more than a day to determine both need and structure. STRING Items (discussed below) were one exception, mainly because of objections by the compiler producers.

1.9. Documentation and Early Versions

As stated previously, the first document describing the language was published in April 1959 (Schwartz, 1959a). It was superseded by another in May (Schwartz, 1959b). The next two language documents appeared in September (Bockhorst and Reynolds, 1959;

Schwartz, 1959c). In early 1960 work began in California on JOVIAL itself in addition to CLIP, so documents began to appear in the spring of 1960 (Shaw, 1960a) on the language JOVIAL and some plans for JOVIAL on computers other than those being developed in New Jersey. However, those versions of JOVIAL were not identical to the East Coast version.

The early use of the interpreter (for language version J0) occurred in January of 1960, about a year after the system was started. The first compiler for the language version called J−1 (J minus one) was available for the compiler developers in the fall of 1959. That compiler was used to program the next version of the language—called J1—which was available in the winter of 1960. This was used to produce the J2 version. The J2 version was delivered in March of 1961 (Schwartz and Howell, 1961). It ran on the IBM 7090, which had replaced the 709 by that time.

The AN/FSQ-31 version of J2 was delivered some months later. Usage of the 709 version really began back with the J1 version of the compiler for the development of utility systems. In Omaha, at SAC Headquarters, it began with the delivery of the 709 J2 version in March of 1961.

What eventually became a standard was the J3 version of JOVIAL. That was originally described by Chris Shaw (Shaw, 1960b, 1964). This version was developed in California. Chris Shaw was responsible for most of the early formal descriptions of JOVIAL.

The first formal presentation on JOVIAL was given at the International Symposium on Symbolic Languages in March of 1962 (Schwartz, 1962).

2. Rationale of the Content of the Language

2.1. Language Objectives

The actual major objective of the original JOVIAL was a language for programming large systems, although it has typically been referred to as a Command and Control Language. These were systems which required the contributions of many people. Also, they would not be constrained to utilize limited sections or instructions of the computer, nor to work with strictly computational problems. These properties certainly seem to serve the Command and Control problem, but serve equally well the programming of a compiler or operating system.

A natural result of this basic objective was the requirement for flexibility. The language had to be able to handle a variety of situations. The necessity for people to use machine language often would not be considered satisfactory, even in those cases in which machine language had always been assumed necessary in the past.

Another language objective was a reasonable level of machine independence. The fact that two compilers for two totally different computers was the original contractual objective of the language helped to achieve this latter objective (Wilkerson, 1961).

2.2. Things Which Were Pretty Much Ignored in the Language

One thing which was given little attention until the first versions of the compiler began to be used to compile themselves was compiler speed. Capabilities were added to the language independent of their effects on compilation speed. This was not true of some other languages being developed at that time, one of which was NELIAC, which has similar overall objectives but tended to emphasize compilation speed to a much greater extent.

Another thing which was ignored was language elegance. An example of this was given previously in the discussion of how the Data Description part of the language was developed. Almost everyone on the project had no foundation in language design, including the managers. Consequently, although the example of IAL existed for a relatively formal description of a language, the formality of JOVIAL tended to be ignored. This could not have been completely bad, I think. It certainly had its weak points, but in fact JOVIAL actually turned out to be very natural for people to use. Many language features were developed as actual needs were recognized, leading to useful, if inelegant, results. The Data Definition area easily fits here. It contained quite a bit of flexibility and power, along with reasonable programming transparency, but syntactically was a string of hard-to-memorize characters required in specific sequence. Long string constants were defined in a very awkward way (e.g., 18H (THIS IS AN EXAMPLE)), requiring considerable counting and recounting for changing. The use of the symbols "($" and "$)" for liberally used brackets was a bad choice. Imprecision in semantic definitions did not help in making all versions totally compatible, even when there were attempts at compatibility.

Another thing which was ignored was standardization with other efforts. Even other efforts within SDC at that time were ignored—partially because of the need for (if not the achievement of) meeting of schedules on the SACCS effort. It was also partially because of the physical distance between the JOVIAL efforts (for much of the time period of the Project, the coast-to-coast trip was by propeller-driven aircraft) and the not unusual tendency for people to ignore other people's work. And the initial inspiration of IAL didn't lead to continued following of it. No further attention was paid to IAL (or ALGOL, as it was eventually called) after the initial design.

2.3. Things Excluded in the Language or Given Little Attention

One of the major initial exclusions of the language was input–output. This can be attributed to SAGE. In the SAGE system no program except the central control program did any input–output. Consequently, it was felt that the great majority of programs would not require input–output for the SACCS System. JOVIAL thus did not include it initially. Eventually, subroutines were written and called Through Procedures (Bockhorst, 1961). One of the original omissions (and still omitted) is interrupt handling or any other obviously real-time instruction or capability. Instead, JOVIAL gave access to parts of the machine through various operations and modifiers. These included access to parts of words in arbitrary groupings of bits or bytes, which allowed one to inspect interrupt or message registers, therefore obviating the absolute need for more direct commands in this area. In the initial versions of the language no real debugging facilities were added. But the Communications Pool provided capability for supporting systems to give considerable debugging capability at both the individual program and system level. Also, no data allocation statements were put into the initial version of the language.

One thing which was allowed in the language but somewhat ignored in the compiler were multidimensional arrays. The language provided for them, but the efficiency of handling anything more than a single subscripted variable was not stressed in the compiler.

(However, single-subscripting was handled quite well.) This resulted in relatively little interest in JOVIAL for programming multidimensional matrix problems. It was felt, in justification of the latter, that the use of multidimensional arrays for the kinds of systems for which JOVIAL was to be used would be minimal.

2.4. Major Language Features

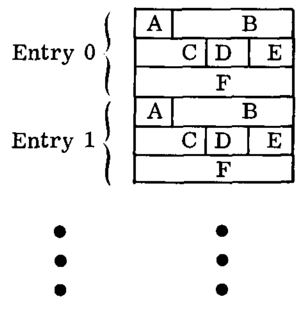
The basis of JOVIAL taken from IAL included such things as compound statements. The use and syntax of compound statements was the same as defined in IAL. The major operators were generally the same, including a switch which was similar to the IAL switch. The statement structure, labelling, and ending were the same. Procedure calls, at least initially, were similar to IAL's, and the general loop structure and FOR statements were similar.

The biggest departure (and the original one) from IAL was in the Data Definition area. Where IAL provided primarily for floating point arrays and some integer values, the JOVIAL language included at the lowest data description level entities which were called "items" (based on the SAGE term) which had a variety of types. The types included floating point, fixed point (where the scaling was specified to be a part of the item), Hollerith and Standard Transmission Code character strings (in the initial version, these were limited to reside within one computer word), and status valued items. These latter represented with symbolic values finite states such as GOOD, FAIR, and POOR, or ON and OFF, or any predefined set of values. In the JOVIAL program these are referred to by the symbolic names (e.g., IF WEATHER = V(CLOUDY)), although internally they are assigned integer values by the compiler.

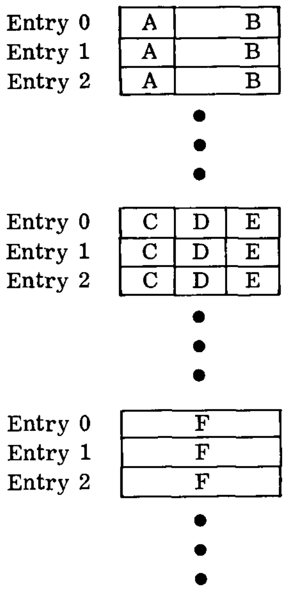
Items were assigned to the next higher level of hierarchy, which was an "entry" in JOVIAL. Each entry contained all of the elements or the items that were necessary to describe particular objects (such as Aircraft and Persons). All entries for an object were contained in a "table", the top level of the hierarchy.

Tables could take on several forms. These were serial, parallel, and variable.

In the serial table, all words containing an entry were contiguous. As an example, a serial table containing the items A, B, C, D, E, and F in a three-word entry would appear as follows:



A parallel table containing the same items could appear as in the following:

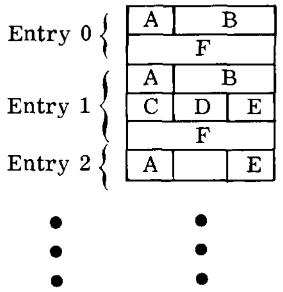


Indexing in both cases with JOVIAL was independent of the entry size or parallel/serial format. For example, the sequence:

```
FOR I = 0, 1, 10$
D1($I$) = 5$
```

would set D1 in the first 11 entries to the value 5 for either of the above (and would work in the serial case if fewer or more words were in an entry).

It was also possible to utilize a variable format which might have a different structure for each entry, as follows:



In the variable case, there would normally be some item in each entry (say A1 in this example) which would provide assistance in stepping from one entry to the next. This was not done automatically by the compiler. A sequence of the following kind would be possible:

```
          FOR I = 0$
BEGIN X1.   IF A1($I$) = 3$ D1($I$) = 5$
          I = I + A1($I$) $
          IF A1($I$) = 0$ STOP $
          GOTO X1$
END
```

This sequence would set all existing D1s to 5 until the end of the table, where only three word entries contained D1, and the end was signaled by an A1 equal to 0.

Another data type was added to the language—much to my chagrin because of its awkwardness—during its early implementation. This was called STRING and it provided for a rather complex combination of character string elements in a variety of formats within an entry. This went beyond the original concept of items and character string items. (This was one of the only "committee type" additions to the early language.)

These data types and data structures provided for a comprehensive capability for access to almost any configuration of logical or arithmetic values. Items could be either full or part words. (No item could be more than one word. This was changed in later versions of the language.) Also, access to parts of items (discussed below) was provided. The point of this was not only the definition of data structures. It was to provide it in such a way that the programmer would not need to know where the item was placed within a word, which word in an entry it was in, and in most cases the size of the items and other facts about it. In some cases, the type itself did not have to be known.

Thus, the JOVIAL program could remain largely unaffected by changes in the data description. That was a crucial part of the language. Also, in some ways this capability was used to show that in fact JOVIAL would produce more efficient code for programming systems than the machine language as used for SAGE. The following type of example was used as an illustration.

In SAGE, "pseudo-instructions" (macros) were used in machine language when referring to Communication Pool items. The purpose was to prevent any assumptions about the size or position of items by programmers while producing reasonably good code for specific situations. (Programs had to be reassembled when the Communication Pool changed.) Four such pseudo instructions were:

ETR	Perform an AND to the Accumulator with a mask the size and position of the item.
POS	Shift the accumulator so that the least significant bit of the item is in the least significant bit of the accumulator.
RES	Shift the accumulator left so that the least significant bit of the accumulator moves to the least significant bit position of the item.
DEP	Deposit into the word containing the item from the proper bit positions of the accumulator.

At least one instruction was generated for each pseudo-instruction.
Thus, to add two items and store in a third, the following sequence had to be used.

```
CLA  ITEM1   Move ITEM1 to accumulator
ETR  ITEM1
POS  ITEM1
STO  TEMP    Save ITEM1
CLA  ITEM2   Move ITEM2 to accoumulator
ETR  ITEM2
POS  ITEM2
ADD  TEMP    Add the two items
RES  ITEM3
DEP  ITEM3
```

This sequence generated a minimum of 10 instructions (on the SAGE computer). In JOVIAL, the same operation would appear in the following statement:

```
ITEM3 = ITEM1 + ITEM2$
```

Depending on the definitions of the items, this statement could generate as few as three instructions because of the capability of the compiler to analyze the entire statement.

The Communication Pool is essentially the Data Definition for all items and tables to be used by the subprograms of the system. In some versions of JOVIAL compilers the Communication Pool is syntactically identical to the Data Definition section within a program. In other versions, however, the Communication Pool actually has a different format from the Data Definitions and has more information than the JOVIAL programs themselves permit. Such things as allocation information can be put into the Communication Pool for both programs and data. The Communication Pool is used for more than compiling programs. It can also be used for such things as simulating data for testing. It allows for the entry of the item name and its value without the programmer having to specify where to place the value or its internal form. The Communication Pool also can serve as a tool for data reduction after tests are run. This is because the Data Reduction Program can examine the information as it exists after a run and use the Communication Pool definition to translate it to a readable form for the user or the tester (Tjomsland, 1960).

Another significant feature of the JOVIAL language from its earliest version was the provision for access to bits and bytes of items. Modifiers for this provided access to a variable number of bits or bytes of the item, starting from any position within the item. The expressions are BIT ($*i*,*j*$)(*item*) and BYTE($*i*,*j*$)(*item*), where *i* is the starting bit or byte and *j* the number of them. These provide a good deal of power. However, the efficiency of this form when *i* and *j* are both variable is at best adequate, but normally much worse. The simpler expression where only one of a constant number of bits or bytes was referenced can produce more efficient code.

Access to entries of tables also was given in JOVIAL. Thus, one can move whole entries other than on an item-by-item basis. A modifier was provided which provided access to the count of entries in a table for use or modification. For example, the statement NENT(TABLE) = NENT(TABLE) + 1$ increments the count of entries in TABLE.

Some other rather unique forms were added to the early JOVIAL to resolve certain problems. One was the CLOSE Statement. This provided for a closed subroutine with no entrance or exit parameters, but it maintained and could use the value of a subscript when it was within its domain of definition. The LOC modifier was added. This modifier, which stands for "(absolute) core location," provided the capability of getting to the location of a part of memory. The expression LOC(TABLE or ITEM) enabled one to reference relocatable information. Today, pointers can be used for this without some of the awkwardness and inadequacy available only with LOC. Another kind of flexibility which was provided (and which created problems for compiler writers) was the fact that the step factor in the FOR statement (FOR I = A, B, C; with B being the increment or the decrement for I) was allowed to be a variable. It could be either negative or positive, and in fact during the loop was allowed to change sign. Of course, that was not the normal case, but the need for providing for it in the compiler was one of those things which created some of the early compiler problems in achieving efficiency and speed.

NENT, BIT, BYTE, LOC, ENT, MANT, and other terms are examples of functional modifiers which were added during the early development of JOVIAL. These were utilized to satisfy a number of the problems which required language solutions. They can normally be used in "right" or "left side" expressions. For example, the statement

```
BIT($I$) (ITEM) = 1$
```

causes the Ith bit of ITEM to be set to 1. (When the number of bits or bytes is 1, it doesn't have to be specified.)

Although the purpose of the language was to provide for machine oriented programming without the use of machine language, the originators were realistic enough to know that there would be a requirement for the use of machine language, at least occasionally. Particularly in the early versions, at a minimum, access to input and output required some machine language operations.

Access to machine language is easy in JOVIAL. The operator DIRECT signals the beginning and the operator JOVIAL the end of machine language. Within the machine language, it was expected that users would need access to JOVIAL (and Comm Pool) defined items and tables. Thus, an operator was defined to give access to these from within the machine language part of the program. This operator was called ASSIGN and it permitted one to place an item in the accumulator or the accumulator to an item. The compiler automatically took care of the shifting of the item as it would in normal JOVIAL statements. (The scaling of the accumulator was specified by the programmer in the ASSIGN statement.) Actually, the ASSIGN combined the functions available in the pseudo-instructions of SAGE shown above. Another capability of interest was called the Item Switch. A Numeric switch is provided as in IAL for a series of branches based on normally continuous integer values of an item. But this was not sufficient for things like status items which were, first of all, symbolically named where users could not assume values for the names. Also, the Item Switch could be used for other item types such as character strings, which can have quite random values.

2.5. Language Design Methodology

The primary technical driving forces for JOVIAL are quite clear. Given that the basic structure would be that of IAL, the major question was what would have helped in the programming of SAGE, since it was assumed that the programming of SACCS would have a similar set of problems. These included the use of a large number of people, different types of data, more logic operations than calculation, and the need for item packaging to save space and access certain machine registers. For example on the SAGE computer there was no floating point arithmetic. Everything was fixed point. So, although the SACCS computer had floating point, it was assumed that fixed point arithmetic would be useful for it as well. Other major influences were those things found necessary to program the compiler itself. That was the source of most of the early modifications to the language. Other ideas came from early users who were beginning to use the language. They discussed and wrote about problems that they had found in using the language.

It would be quite an extreme exaggeration to say that a strict methodology or control system was used in developing the JOVIAL language. As stated earlier, much of the development came from innovation when needs were recognized. Most problems were resolved by adding to or modifying the language. Many problem resolutions had as a goal the obviation of the need to resort to machine language. This mode of working led to some extremely fast decisions, some awkward syntax, some difficulties for the compilers, but a quite practical and usuable language.

The basic approach was essentially as described before. The base language was chosen, and it was initially implemented in a variety of processors. Compiler work was begun with a minimal form of the language. Data Definitions were added for the total range of data that was to be needed both for the compiler and for the application systems. As time went on, modifiers and other forms were added as need arose. The language continued to evolve for some years thereafter, both within the original effort and in California and other places as the language was used elsewhere.

3. A Posteriori Evaluation

It is always difficult to provide an accurate objective account of a product's success or failure (even when one's name isn't directly involved). This is true for many reasons, including the fact that nothing is ever absolutely good or bad. But the following attempts to present a reasonable assessment of JOVIAL's effect on the world.

3.1. Meeting of Objectives

In general, it seems that JOVIAL met its goals. There have been a large number of systems of many types produced using JOVIAL. Most of these have been for areas which up until the time when JOVIAL was developed were not thought programmable in other than machine language.

For the first decade of use there were really never very many serious complaints about the language capability (after the first year or two of development). The difficulties and complaints tended to be largely the result of early implementations. The early compilers were, to put it mildly, not very reliable. They were extremely slow. The first compiler on the 709 took eight hours to compile itself. In those days the probability that one could compile for eight straight hours and get a properly punched binary deck for output was less than 0.5. Of course this slowness was also recognized when compiling other sizeable programs. This, combined with the fact that the compiler might produce erroneous results, could dampen even the most ardent enthusiasm. But even with these kinds of problems, there was little drive on the part of early users to disassociate themselves from the use of the language. Rather strong statements were used to point out compiler problems, but once many of the early difficulties were overcome with the compiler the language was considered quite satisfactory.

Another interesting fact was pointed out by someone responsible for teaching early users how to use the language (Rizzo, 1962). The initial capability didn't provide much tutorial assistance, so that learning of the language was not easy and the documentation, although it improved with time, wasn't the best for beginners. But those who were responsible for training and criticized this lack of good teaching aids also pointed out that once people got over the hurdle of learning JOVIAL there were very few questions and very few problems in using what they learned. Most people found the language relatively easy to retain and use for everyday work.

The fact that the SAC organization under Colonel William Shirey in Omaha (the first non-SDC users) continued to use the language on a fairly heavy basis, despite some early tough going, was critical in keeping the JOVIAL language alive. This led to an eventual spread of use in the Air Force. It is also true that its use spread without support from any major manufacturer. Almost all the JOVIAL compilers that were produced until the mid–late 1960s were done under contract to a government agency for a specific system. Manufacturers were evolving COBOL and FORTRAN at that time. Of course a number of other languages were also in development in the period from 1960 to 1965, such as MAD, NELIAC, ALGOL 60, SNOBOL, JOSS, and hundreds of others. But JOVIAL maintained its progress during that period.

The objective of moving JOVIAL–coded programs and the compilers from computer to computer was partially met. The initial effort in New Jersey provided compilers for two computers for the same language almost simultaneously. When one moved a program from a computer with six characters in a word to another which had eight-character words, the fact that the early compilers didn't provide for character string items of more than one word in length certainly made the portability imperfect. Similar results occurred because of the restrictions on scaled fixed point items. However, considering the type of programming which was permitted (much more variable than possible with FORTRAN), portability was reasonable. I'm not sure that it had too much effect on the ultimate success or failure of the language. Most users tended to program for a machine and stay with it on that machine. It is true that very few JOVIAL compilers handled the same version of the language. After the J2 effort, most others produced different subsets of J3.

The objectives for JOVIAL that were set originally were not changed. The flexibility and power of the language continued to be objectives throughout and were reasonably well satisfied. In fact, as people developed the language further there were actually some restrictions put in that did not exist in the early version. These included restriction to equal types for formal and entrance parameters of procedures. Restrictions on the step factor of the FOR Statement were implemented in some later versions.

3.2. Contributions of the Language

It is hard to say what contribution to programming technology in general or to other languages JOVIAL actually made.

There are a number of languages which contain some of the capabilities or characteristics of JOVIAL. Most often they are in a different format and except for certain situations it's not possible to directly relate that language to JOVIAL itself. A good example of this is PL/I. JOVIAL knowledgeable reviewers of PL/I when it was first developed pointed out that many of the characteristics of JOVIAL had been adopted in PL/I. However, there's no official acknowledgement of the use of JOVIAL as one of the bases for PL/I to my knowledge.

Nevertheless JOVIAL had things to offer and, whether directly or indirectly, should have contributed something to the technology. It was one of the first system programming languages and helped show that languages were capable of serving that purpose. It was one of the early, if not the earliest, compilers coded completely in its own language. It provided for data structures, types, and operations that permitted programming outside the realm of the strictly computational. It was even possible to use it for commercial programming. Although certain problems occurred in the early versions with rounding and report formatting, JOVIAL was used for the programming of a wide variety of systems. It provided for access to subparts of elements and words, which in early computers with small memories was very important, and is still valuable today for a variety of things. It was a language really aimed at flexibility and nonconstraint on the program. These were all contributions and valuable factors for the people who used it. They have helped maintain the language's use for a lengthy period, although the initial intent of the language was actually intended for only one specific set of users and a single system.

There have been quite a few versions of JOVIAL. I don't know them all and within each version there were variations with different implementations, so that there is unlikely to be a comprehensive list of all the capabilities that actually were in each version. A list of the names for different varieties or versions of JOVIAL includes: J0 (Olson *et al.*, 1960), J−1, J1, J2 (Schwartz and Howell, 1961), J3 (Shaw, 1961, 1964), and J3B (Department of the Air Force, 1967). This was the original Air Force standard version, J3 being the version developed in California in parallel with the development of J2 in New Jersey for the SACCS contract. Other versions included J4, J5, and J5.2, the latter two being outgrowths of a version called Basic JOVIAL (Perstein, 1968), which was actually an attempt to provide a working version with a fast compiler. (For example, it didn't include fixed point arithmetic). This was developed because of the criticism of the slowness of the compiler. Basic JOVIAL was itself derived from an experimental version called JX2 (developed in 1961), which rivaled other compilers in speed but did not have enough language. When timesharing came in the early 1960s, another interpretive version of a subset of JOVIAL was produced. It had language capability similar to JOSS (if not the elegance) in that it provided for arithmetic, formatting, simple terminal input–output, and other capabilities useful for interactive users. That was a version of JOVIAL which had quite different objectives than the original system programming language. This version was called TINT and was described in a paper at the 1965 IFIP Conference (Schwartz, 1965).

Although the preceding references to the various versions of JOVIAL may appear rather mind-boggling, it is actually probably an understatement. With the exception of some Air Force sponsored versions of J3, little control was exercised over the language. So, for reasons of implementation pressure, computer idiosyncrasies, particular needs or lack of needs, and individual choice, one will note differences within "versions" as well as among different ones. New versions were sometimes labeled after compilers were developed. However, the major aspects generally were implemented, and there was "near-compatibility" in most versions.

JOVIAL has served as a direct contributor to at least several languages. One language which is in use today in Europe is CORAL (Woodward and Wetherall, 1970). Many of the initial concepts for CORAL were taken from the JOVIAL of the early 1960s. A language which has been used by Computer Sciences Corporation for much of its systems programming work is called SYMPL. It consists of elements of JOVIAL and FORTRAN and some other properties developed at CSC. SPL, a Space Programming Language which was developed by the Air Force Space Command some years ago, was based to a large extent on the experience with JOVIAL. Others, such as CMS II used by the Navy and perhaps PL/I as stated before, have had either a direct or some indirect relationship with JOVIAL.

In the early 1970s a group was formed by the Air Staff under Leo Berger to produce a new standard version of JOVIAL. They developed a specification for a language called J73 (Department of Defense, date unknown). There have been several implementations of it, and it is being used on a variety of computers at the present time. This is the first version which, by design, is not upward-compatible with other versions. Some version of JO-

VIAL, or several versions of JOVIAL in some cases, have existed on just about every major manufacturer's computers and some less well-known computers over the years. A minimum of ten companies have produced JOVIAL compilers.

JOVIAL was adopted in the mid-1960s as a standard language (Department of the Air Force, 1967) for the Air Force and that's where most of its use has been. It also was for a short period of time adopted by one part of the Navy (NAVCOSSAT). This adaptation of JOVIAL for the Navy was done on the basis of a comparative study comparing JOVIAL, a number of other languages, and machine language. However, there were a number of criticisms of the particular study, and the future of JOVIAL in the Navy became somewhat tenuous. (An interesting sidelight to that particular study was the fact that the first time it was run the machine language version of the program was assumed to be the base with which to compare other languages' efficiency and size. But the machine language program actually came out worse in these respects than some of the higher level languages involved. This caused the people responsible for the study to rerun it. Machine language fared better the second time.)

In 1961, members of the RAND Corporation conducted a study to compare JOVIAL with FORTRAN to see if JOVIAL or any language really merited being used as a Command and Control language at the time. The actual test consisted of seven problems, five of which utilized multidimensional arrays within several statements. The basis of the test was to see how well these would be compiled. FORTRAN won handsomely on all of the array problems with respect to generated code.

JOVIAL compared favorably on the nonmatrix problems. JOVIAL was much worse in compilation time, which didn't help its cause. In any case, based on that experiment, which seemed inadequate for the choosing of a Command and Control language, the people doing the study recommended that no language be adopted for Command and Control use at that time. The main thing proven by some of this is that we haven't mastered the art of comparative studies. The conclusion may have been right, but it always seemed to me that if so, it was in spite of the method used to reach it (Haverty and Patrick, 1963).

JOVIAL has been used by a variety of services and some other organizations, including the FAA, the Air Force (of course), the Navy (for some things and a variety of research and system projects).

Since the earliest versions of JOVIAL, the most significant changes that have been added are in the area of input–output. There are now a number of input–output commands in the language. Dynamic control of data allocation has been entered through data structure definitions, and pointers have been added in J73. Some syntax improvements have been provided in the language, particularly in the data definition area and in some of the modifiers. Some types have been purified to a certain extent. Originally, arrays and tables were separate. For example, when one defined an array he couldn't include items, and arrays couldn't be part of tables. That has been changed. There are a number of other changes which have taken place. Many of the key ones, of course, are being implemented in J73.

3.3 Mistakes and Omissions

The first major omission which contrained the use of JOVIAL considerably was its lack of input–output. This of course was actually a planned omission from the beginning. But its use for systems other than large systems where it is assumed that just one or several routines would service all input–output is of course diminished by this lack of input–output for individual programs. The lack of formatting and the ability to output or input by format or other convenient means (which is still an official omission from the language) has kept the language at arms length for many applications. Actually formatting has been implemented in at least a few versions. One which included formatting was the interpretive version called TINT (Schwartz, 1965). That was essential for it to operate as an interactive user oriented language. JOVIAL syntax awkwardness in certain areas probably didn't affect its use from the point of view of those who started using the language but helped keep certain communities uninterested in the language. The early implementation problems, particularly the speed and size of the initial compilers, which were 50,000 or more instructions, helped keep down any overwhelming use that might have occurred otherwise. To a great extent these implementation problems were due to the fact that features which made compiling difficult were sometimes added with reckless abandon. And, of course, the lack of efficiency in certain areas—particularly multidimensional arrays—restricted its application by programs which required them. It is unlikely that much interest would have been generated in JOVIAL for programming outside of its major areas of current use even if it had been much improved in these areas. Other languages such as FORTRAN and COBOL are accepted for programming these problems.

3.4. Problems and Trade-Offs

The hurry-up mode in the early versions created incompatibilities among different versions, particularly those separated geographically and those developed by different groups. And, of course, this detracted from portability among versions. The overall emphasis was for flexibility and generality of the language, which in turn led to a variety of implementation problems. This caused reliability, speed, and code generation difficulties. But the trade-off was made. There is a question whether in the long run it was a bad trade-off. The flexibility and the generality were probably worth some initial difficulties. Time for implementation was always a problem in this development. The language was defined rapidly, and the compilers were written quickly. There wasn't a lot of planning by the individuals and the managers concerned, but I think to some extent that this hurrying was as much a question of personalities as pressure. The people who were involved liked to do things in a hurry, were not very academically or research oriented, and they liked to see things run (typical system programmers). So I sometimes wonder if there hadn't been imposed deadlines (which in many cases of course were missed anyway) whether the people would have done a significantly more studious effort. (I'm certain that the tendency to "produce" rather than "study" is true for me, who was responsible through J2.)

4. Implications for Current and Future Language

Certainly, whether or not directly a stimulus, the work that went on in the early JOVIAL is now represented in a variety of ways. System programming languages are quite common. Complex data definition capability in a variety of languages certainly is not unusual today. Much of the system programming language work today is based to a large extent on PL/I, but it is also based on other languages as well. This concept within JOVIAL did prove feasible and valuable.

The original JOVIAL work was not a committee effort. There were relatively few people who actually helped design the language. Most of the people involved hadn't done this kind of work before and were basically implementors, or programmers. The fact that it wasn't a committee effort in many ways created the positive characteristics of the language as well as some of its negative ones. The language did maintain its original objectives, and its major characteristics remained fairly consistent throughout its early development. Perhaps the influence of others who had some better or more experience in this area could have been valuable, but it is also quite possible that with a variety of other contributors, it would have lost some of its flavor. For initial efforts on language design, an individual driving effort is probably a good idea.

I'm not certain what the future of JOVIAL is. The Department of Defense is trying to standardize once and for all on a language. This is one of those efforts which is going to take a long time to resolve. Meanwhile JOVIAL itself is being implemented and used for a number of projects. It has of course much more competition now in the areas for which it was intended. Also, competition from entrenched languages like COBOL and FORTRAN for things outside of what are typically JOVIAL applications, or considered to be JOVIAL applications, is much too intense to assume that it'll ever go beyond that. It's probably more likely that it will continue to have about the same percentage of use in the world as it has had until now. Hopefully, it will have influenced the Department of Defense standard language [Ada] which is eventually chosen to some degree.

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JULES SCHWARTZ: Thank you. If I appear sleepy today there's a good reason. Yesterday, during Al Perlis's discussion, I learned for the first time that when the first ALGOL specifications were published, the committee already knew that the name was to be changed to ALGOL. But they published the specifications using the name IAL (International Algegraic Language). So I've been plagued all night with the specter of the ALGOL committee having decided to call the original specs ALGOL. In that case, what would be the name of the language we're discussing today? JOVALGOL just doesn't work.

Well, as we already know—and of course, you know today if you didn't know yesterday—when the development of JOVIAL began, the world of computing was quite different than it is today. Computers were vacuum tube based; most were quite small, even relative to today's small computers. Utility routines such as one-card load programs, and small memory dump routines, were used as individual programs rather than part of major systems controlled by a job control language. Assembly language programming was used in most environments.

My own experience with things like languages and compilers was limited to several things. One was work on the PACT [Project for Automatic Coding Techniques] language that was described in the 1956 ACM Conference, which, although called an automatic programming language, was not syntactically anything like ALGOL or FORTRAN. I, with several other people, namely, Irwin Book of SDC and Harvey Bratman also of the System Development Corporation, had experimented with the expansion of algebraic and logical expressions, based on an article in an ACM *Communications* of 1958 by H. Wolpe of IBM. Other than that, and reading the IAL (International Algebraic Language) specifications, my language experience was nil.

By the time JOVIAL began, one large Command and Control System had been developed, and was in the process of its initial installation. The development of it had started in 1954. It was called SAGE, and it was a system built to track and intercept hostile aircraft. It had a significant influence on JOVIAL.

The actual design of JOVIAL began in 1958. Its purpose was to program another large Air Force Command and Control System called SACCS, with the actual designation 465-L. JOVIAL has been called a command and control language because of its use for systems like 465-L. However, I prefer to call it a system programming language. A demonstration of its capabilities can best be described, I think, by listing the objectives of the language when it was developed, and presenting brief examples of how JOVIAL satisfied these.

The major objective of JOVIAL was to permit people to program complete systems in a higher level language. This capability was provided through various facilities, the first one being a comprehensive data definition and referencing capability.

[Frame 1] gives an example of part of the data definition capability. Now, incidentally, through all these examples, you'll see dollar signs liberally sprinkled. This should not

```
ITEM XYZW    F   $                          Floating Point
ITEM RMN     I   7 S $                             Integer
ITEM XTUVW   A   14 U 6 $                      Fixed Point
ITEM ABC1    H   5 $                             Hollerith
ITEM VIX     S   V(CLOUDY)
                 V(RAIN) V(FAIR)$                   Status
```

Frame 1. Items—examples of definitions.

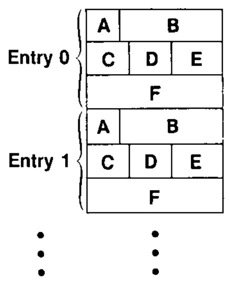
```
TABLE      RQW2  V    150    M$         Variable-length, serial,
                                        medium-packed
  BEGIN    ITEM...$
           ITEM...$                        .
            .
            .
            .
  END
```

Frame 2. Tables.

be construed as an indicator of wealth, greed, or success on my part. When the language was first implemented, there was, as we all know now, a shortage of characters available on keypunches. In this case we decided to use the dollar sign to help form the character set. One major place they are used is as end of statement symbols, as can be seen. The other is as part of left and right brackets, to help form the left and right subscript brackets, which will appear later.

Now, [Frame 1] illustrates the definition of items. Items are the lowest level of named objects in the language. These are five examples of item definitions as they originally existed in the JOVIAL language. Each one illustrates a different type of item. Item XYZW is defined as a floating point item, by the character F. The second item, RMN, is an integer item. It has seven bits and it's signed; the S means it's signed. The next item is a fixed point arithmetic item. It can be used for numerical calculations with fixed point arithmetic. It has 14 bits and the 6 means there are 6 bits to the right of the point; the U means there is no sign; it's always positive. The next item, ABC1, is a Hollerith or character string item. It has five characters. The last item is a status item. It provides for name values of an item without committing the programmer to know or to specify in code the actual numeric values for the values. Internally, however, the item is assigned a numerical value for each of the statuses represented. The statuses, in this case, are CLOUDY, RAIN, and FAIR.

[Frame 2] represents some of the kinds of structures that were made available with JOVIAL. (Actually the next five slides) The major structure is called the table. The first example here is table RQW2. Table RQW2 has a variable length designated by V, meaning that it can have a varying number of entries, where an entry is a set of items. This particular table has a maximum of 150 entries. This can be seen in the header. And it is to be "medium packed"—M stands for "medium packed," meaning that the compiler will allocate the individual items of the table to fit into machine-oriented parts of the computer



Frame 3. Serial table—example.

```
TABLE   RMT3      R   75 3 P$          Fixed-length, Parallel,
                                       Hand-packed
BEGIN   ITEM XY   I   15 U 2 4 D $     Word 2, BIT 4, Dense
          .
          .
          .
```

Frame 4. Parallel table.

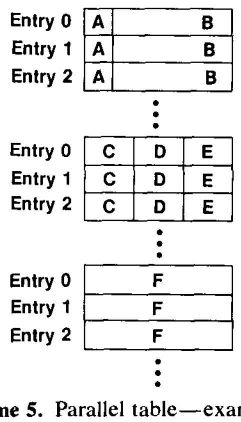
word which are easily accessible. In the early days of JOVIAL these would most likely have been the address field, the operation field, and a few others. Today most machine-oriented fields probably could be bytes or characters.

Following the table header, the definition of an entry is included between the BEGIN and END. That's where the items are listed.

Table RQW2 is defined as a serial table. Actually it's defined as a serial table by using the default which in this case implies "serial." An example of a serial table is [in Frame 3]. A serial table groups all items of an entry into a contiguous set of words. Entry 0 is the first entry; Entry 1 is the second, and all items within that table are in contiguous words.

Table RMT3, whose definition is [in Frame 4] is defined by the P as a parallel table. The parallel format is illustrated [in Frame 5]. The parallel table is structured so that moving between entries on the same item, such as from A of entry 0 to A of entry 1, is in increments of 1, and between words within an entry, such as from item A of entry 0 to item C of Entry 0, is done by incrementing by the number of entries. That's the parallel structure.

Getting back to table RMT3 [in Frame 6], it's defined as fixed length by the R (for rigid table). This means that it has a fixed number of entries. 75 is the number of entries. In this case, the number 3, which follows the 75 in the header, means that there are going to be three words per entry, and the fact that this is stated in the table definition means that the programmer himself will assign item positions within each entry. Again, the definition of the entries or the items within the entries follows the table header. The difference between these and the other item definitions discussed before is that the programmer will provide information such as word 2 of the entry, bit 4 of the word for the starting position, and D for "dense"—dense as opposed to medium packed which we saw before. Dense means



Frame 5. Parallel table—example.

```
TABLE    RMT3      R    75 3 P$           Fixed-length, Parallel,
                                          Hand-packed
  BEGIN  ITEM XY   I    15 U 2 4 D $      Word 2, BIT 4, Dense
           .
           .
           .
```

Frame 6. Parallel table.

it's not going to be accessible by referencing a machine field such as the address or operation codes. In other words, the dense item is tightly packed within a word.

Also in JOVIAL one can define arrays. Arrays of any number of dimensions were possible in the original versions of JOVIAL.

After structures and items, the next major capability which provided for generalized programming was direct access to bits and bytes, or characters, within items in JOVIAL. The next slide [Frame 7] shows examples of that use. The first example says: set bit 3 of IT3 (the item IT3) equal to 1. The second example as it would be stated in JOVIAL would set the two bytes, starting with the Ith byte of Item HXY to the two bytes of Item PRQ starting with the Jth byte.

The last example says to set the J bits of the Xth occurrence of item MNP, starting with the Ith bit to the J bits starting in bit K of the Yth occurrence of item RQL. In other words, you're setting a variable number of bits to a variable number of bits from one item to another where both items are indexed.

A second major objective of the language was freedom from machine specifics. Although the programming of very general and system oriented functions was permitted, one of the ways this was done was through a set of modifiers. Some of the modifiers are shown [in Frame 8]. With NENT one can access or modify the number of entries in a table. MANT gives access to the mantissa of a floating point number, CHAR, the characteristic, SIGN, the sign of an item, ENT, the whole entry of a table, and LOC, the absolute location of a table. An example of the syntax and use of a modifier is shown at the bottom of the slide.

In the first example at the bottom, the number of entries of table TABX is incremented by 2. It's set to the number of entries of the same table plus 2. And in the second example, the sign of item1 is set to 1. (Actual statements in JOVIAL would have had dollar signs at the end.)

The third objective of JOVIAL was an attempt to make the program independent of the data definition. That is, although the data definition could change, the program itself should remain unchanged. One example of this is the ability to mix data types in a variety of ways, within arithmetic expressions, on assignment statements, and elsewhere.

Another example of freedom from the data definition shows in the kinds of switches JOVIAL allows. First of all, it allows the subscript or numeric switch, where the switch point was simply based on the value of the subscript and the switch call, such as the first example on the next slide [Frame 9], where one branches to ABLE subscripted by I. In this

```
BIT($3$) (IT3) = 1$
BYTE($I, 2$) (HXY) = BYTE($J, 2$) (PRQ)$
BIT($I, J$) (MNP($X$)) = BIT($K, J$) (RQL($Y$))$
```

Frame 7. Bit and byte—examples of use.

NENT	Number of Entries
MANT	Mantissa
CHAR	Characteristic
SIGN	Sign
ENT	Entry
LOC	Location

Use Example

```
  NENT(TABX) = NENT(TABX) + 2
  SIGN(ITEM1) = 1
```

Frame 8. Modifiers—examples.

case, the branch would be the "Ith" label on the switch declaration. Another kind of switch initiated in JOVIAL was called the item switch. In this switch, the value of the switch point is contained in an item and may not necessarily be chosen from a set of sequential integers known by the programmer. In this case, the switch labeled BAKER is based on the value of the item RPQM which is a status item, the values you see to the right: CLOUDY, RAINY, and FAIR. This call will go to R1, R2, or R3 depending on whether the value of RPQM is CLOUDY, RAINY, or FAIR. And of course, in this case the item could have had more values than just CLOUDY, RAINY, or FAIR—all of which are unknown to the programmer.

Another example of independence from data structure in programs is on the next slide [Frame 10]. This particular program, without going into detail, cycles through a table setting values of DX based on the values of AB. It does it whether the table is serial or parallel, and independent of the number of words in an entry. So that if the structures involved change from serial to parallel, or parallel to serial, or the number of words changes in an entry, the program doesn't have to change.

In addition to these capabilities, JOVIAL does provide rather easy access to machine language, although the object has always been to avoid its use as much as possible. Another objective of the language, and probably one of the first languages with this objective, was that the compiler should be written in its own language. JOVIAL compilers were always programmed in JOVIAL.

Some of the basic ideas for the language came from the programming of SAGE. It was the first large real time system, utilizing about 1000 or more people for development and installation. SAGE provided ideas for the kinds of facilities that would be needed in a language to program large systems. One of the key ideas of SAGE was in the area of data definition. SAGE was programmed in machine language but used the concept of a central data dictionary. This concept was implemented with the Communication Pool, or Comm Pool, which was the central data definition used to assemble programs. The SAGE Com-

Subscript (Numeric) Switch

```
  SWITCH ABLE = (S1, S2, S3...Sn) $          Declaration
  GOTO ABLE($I$)$                            Call
```

Item Switch

```
  SWITCH BAKER(RPQM) = (V(CLOUDY) = R1, V(RAINY)
                     = R2, V(FAIR) = R3)$ Declaration
  GOTO BAKER($I$)$                        Call
```

Frame 9. Switches—examples.

```
FOR I = ALL(AB)$
BEGIN
  IF AB($I$) = 3$
  DX($I$) = 5$
END
```

Frame 10. Accessing tables independent of structure.

munication Pool also provided definitions of items of the various types that were eventually defined in JOVIAL. The Comm Pool capability was applied to JOVIAL, permitting the data definition to exist outside of programs.

SAGE provided a scheme for accessing data through pseudo-instructions to permit constant programs even when changes were made in the central data definition.

[Frame 11] gives an example of how that was done in SAGE. Again, I'm not going to go into detail, but there were operators in the machine language programs, such as ETR for Extract, Position with POS, and Restore and Deposit. These were pseudo-instructions in SAGE. Using these, the programmer did not have to know the actual positions of items within words, but could manipulate them anyway, such as in this example of an addition of two items.

One of the problems with this technique as used in SAGE was that to add these two items together—ITEM1 + ITEM2—which is shown on the bottom of the example, took a minimum of 10 instructions, one for each pseudo-instruction. One of the arguments used for the development of JOVIAL was the fact that one could have the same data transparency, plus the generation of more efficient machine code with JOVIAL than was possible with machine language, because the compiler could take advantage of the particular situations of ITEM1, ITEM2, and ITEM3 to do the same operation, and actually turn out better code.

So SAGE was one of the major contributors to JOVIAL.

The other very strong contributor to JOVIAL, and actually the basis for the architecture and the name of the original language, was the definition of IAL, later called ALGOL. This definition appeared in 1958 in the *Communications of the ACM*. The basic structure of JOVIAL, and of course many other languages, was taken from IAL. A number of

```
SAGE:
  CLA ITEM1     Move ITEM1 to accumulator
  ETR ITEM1     Mask ITEM1
  POS ITEM1     Position ITEM1 to the least significant position
  STO TEMP      Save ITEM1
  CLA ITEM2     Move ITEM2 to accumulator
  ETR ITEM2     Mask ITEM2
  POS ITEM2     Move ITEM2 to the least significant position
  ADD TEMP      Add the two items
  RES ITEM3     Move to position of ITEM3
  DEP ITEM3     Store in ITEM3
JOVIAL:
  ITEM3 = ITEM1 + ITEM2$
```

Frame 11. Accessing items in SAGE—adding two items.

changes were initially made to IAL for JOVIAL, particularly in the data definition area, but as time went on, no attempts were made to incorporate concepts from succeeding versions of ALGOL, not at least in the first few years.

Another of the very important subjects of JOVIAL was schedules. This was not always a happy subject in the days when JOVIAL was being developed. The original contractual commitments were for several compilers to be produced by System Development Corporation in parallel, one on the IBM 709, and the other on the AN/FSQ-31 Computer. The IBM 709 version, according to the contract, was to be delivered within six months, the Q-31 some months later. The work began at the end of 1958. The actual first formal delivery of the JOVIAL 709 compiler was made to SAC (Strategic Air Command) in Omaha in early 1961. A little calculation will show that it missed the original schedule by a fair amount.

However, a variety of intermediate versions of JOVIAL processors was produced prior to the formal delivery and used for a number of in-house activities, one of which was programming the compilers.

Another interesting aspect of this development in retrospect was the management practices used at the time. Today there are probably more people that have worked with compilers in the world than there were total programmers in the world at the time of the JOVIAL development. The only person with previous experience on the original JOVIAL project was myself, and at best my experience was very distant and limited. The project that developed both the 709 and the Q-31 compilers varied in size from around 6 to 15 people over its life. For some of these people—and a fair number of them—this was their first programming job. They were hired to do this and trained. Management practices were, to put it favorably, informal. To put it bluntly, almost nonexistent. One of the major problems with management was that the language was evolving as the compilers were being implemented. Major language features were developed in literally minutes! With minor exceptions, there were no committees involved. One couldn't define things in minutes with committees. The fact that there were no committees involved in the original version of JOVIAL, was, I believe, good for the development. Most of the early features were added by me, or one of several others working on the project (most of the time with my concurrence).

Frequently, language features were determined as needs were recognized by compiler writers who were programming in JOVIAL. Features were also put in or changed as early users began to use it, in-house users, generally.

No complete language description existed at the beginning of compiler building. Informal documents were written which served as an adequate baseline, but frequently compiler code was produced based only on spoken communication. Updates of previous documents were eventually produced, after things were implemented in most cases. The first comprehensive attempt for a stable language description was produced at the time of the first compiler delivery, which was about 2½ years after the project started.

Other formal JOVIAL language descriptions were written in the following years. They were written mostly by people associated with another version of JOVIAL being produced by SDC on the West Coast. You have to understand—the version I was talking about up to now was produced on the East Coast, for 465-L. The West Coast efforts initially produced compilers for computers other than the ones that were being used on the East Coast. An example of these computers were the Philco 2000, the AN/FSQ-7, which was the original SAGE computer, and the CDC 1604, among others. However, these efforts generally were also for versions of JOVIAL other than the versions being produced on the East Coast.

The West Coast team grew from the early experimentation with expression analysis which was worked on by Bratman (SDC), Book (SDC), and myself. When I left for the 465-L effort in 1958, that nucleus expanded and continued research into languages and compilers. A language called CLIP evolved from this effort, in parallel with early JOVIAL work on the East Coast. However, as time progressed, more effort was devoted to JOVIAL on the West Coast and the work on CLIP eventually stopped.

But the West Coast group continued with expansion, refinement, and formalizing of JOVIAL, and in fact, are responsible for the version that eventually became the Air Force Standard. Most of the formally published literature on JOVIAL was written by Chris Shaw on the West Coast. He's now at Xerox.

As the years continued, many other companies became JOVIAL compiler producers. Examples are PRC, CSC, Abacus, SofTech, and a number of others. Computer manufacturers were not a major factor in producing or preserving the language initially, although versions of JOVIAL have existed for almost all major and not-so-major computers that have been in existence since those days.

With all these companies and computers, and with the exception of the eventual Air Force published standard, very little control over the language existed, and a great number of variations were eventually produced.

These are some of the versions [Frame 12]. These are each a version of JOVIAL, J0, J−1, J1, J2, . . . it goes on. If this isn't sufficiently mind-boggling in its size, it should be realized that it isn't a complete list. And for each of these variations, different subsets of that variation were produced within compilers. In summary, although someone familiar with a particular version of JOVIAL would probably recognize other variations as being part of the JOVIAL family, he would also find that he'd better study the specific version very carefully before producing any code.

JOVIAL did prove to be quite general and useful for a sizeable number of tasks, but several areas of concern stand out quite distinctly in my mind. First, the original compilers were slow—very slow. One of the things which was not a concern when language features were being designed was the effect of a feature on the compiler. This was coupled with the language's emphasis on generality and the use of fairly slow computers by today's standards. Also there was the rather small level of experience of the staff, although most of the people were quite good, and quite hard-working. Also, the compiler was programmed in

J0 J-1 J1 J2	The Original East Coast Set
J3 J3B	The West Coast Versions—The Eventual AF Standard
BASIC JOVIAL JX-2 J5 J5.2	Relatively Fast Compilers
J73 J73I	Current AF Developed Versions

Frame 12. Some versions of JOVIAL.

its own language. All these things contributed to long periods of compilation. At first it took eight elapsed hours to compile the compiler on the 709, and that's with nothing else running on the computer. Also, for a variety of reasons, some of which are probably obvious, the initial compilers were not very reliable. This, together with the lack of speed, not infrequently led to long periods of waiting for wrong or nonexistent results. This caused considerable tension on the part of early users! It also created a fair degree of strain for those of us who had their names associated with the language!

Even with these and other problems, however, the language continued to grow in use, and there was no significant attempt to avoid its use among most of the early users. It did prove to be quite general, although not elegant syntactically nor particularly easy to learn; it was easy to use, and once learned, easy to retain. It has been used for a wide variety of programs, many of which were other than Command and Control Systems. It has been compared against other languages in contests of various kinds, and has usually come out fairly well. It was probably the first language with a large compiler totally programmed in itself, and it was also the very first, (or near to it) System Programming Language. It was one of the first high-level languages used for total programming of a large Command and Control System.

JOVIAL, in a variety of flavors, continues to exist today and to be used for numerous applications. The newest versions have resulted from an Air Force–sponsored design committee's efforts begun in the early 1970s. These are the J73 versions which appeared on the last slide. Several other languages have used JOVIAL as part of their original design basis. Some languages, such as PL/I, now have quite similar kinds of objectives and capabilities, although it's not clear that their design was based directly or indirectly on JOVIAL itself.

The Department of Defense is in the process of trying to find a standard language, and a few versions of JOVIAL have been part of the several languages examined for this standard. If JOVIAL is not chosen, its use will probably decrease over the next decade. But considering that JOVIAL originally had very short-range objectives, narrow support, the rather over-ambitious nature of the original efforts, and a variety of other early problems, it has survived and been used in a larger number of situations than one might have expected. It has been and will most likely continue to be used for some time. This provides great satisfaction to its early developers, who thought of it in very short-range terms back in 1958.

Thank you.

TRANSCRIPT OF QUESTION AND ANSWER SESSION

JOHN GOODENOUGH: One of the questioners, John Favaro, asks (I'm going to rephrase a bit): One of the arguments you said that was in favor of developing JOVIAL was the fact that you could develop more efficient programs using it, although it seems with most other languages, people are always concerned that if you're developing a system implementation language, it'll be less efficient than using assembly language. Was there really a lot of opposition to that argument at the time?

JULES SCHWARTZ: Yes, of course there's always opposition, particularly in some areas. For example, JOVIAL did allow an unlimited number of dimensions for arrays, but little its own language. All these things contributed to long periods of compilation. At first it took eight elapsed hours to compile the compiler on the 709, and that's with nothing else running on the computer. Also, for a variety of reasons, some of which are probably obvious, the initial compilers were not very reliable. This, together with the lack of speed, not infrequently led to long periods of waiting for wrong or nonexistent results. This caused considerable tension on the part of early users! It also created a fair degree of strain for those of us who had their names associated with the language!

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JULES SCHWARTZ: Yes, of course there's always opposition, particularly in some areas. For example, JOVIAL did allow an unlimited number of dimensions for arrays, but little use was made of this feature. It was very inefficient once one got beyond a single subscript. But in the area I was talking about, which provided the ability for programs to refer to tightly packed or otherwise structured items without having to worry about where they were in the word, JOVIAL did provide the ability for the compiler to produce better code for a particular setup than the programmer himself. In that area, and some others (including single dimension arrays), it did quite well.

GOODENOUGH: A couple of people have asked, "What communication did you have with people implementing other ALGOL 58 dialects, such as MAD and NELIAC?"

SCHWARTZ: Almost none with MAD. NELIAC—there was communication after one of the contests. It was an experiment to compare the two to see which language the Navy would use. NELIAC was the Navy base language, originally. JOVIAL wasn't. And in at least one version of the contest, JOVIAL was chosen by the Navy. That created a lot of communication! But JOVIAL didn't stay as the Navy language. [As far as ALGOL, eventually there was communication, but it didn't have continued influence on the early JOVIAL.]

GOODENOUGH: You mentioned that the term "byte" is used in JOVIAL. Where did the term come from?

SCHWARTZ: As I recall, the AN/FSQ-31, a totally different computer than the 709, was byte oriented. I don't recall for sure, but I'm reasonably certain the description of that computer included the word "byte", and we used it.

FRED BROOKS: May I speak to that? Werner Buchholz coined the word as part of the definition of STRETCH, and the AN/FSQ-31 picked it up from STRETCH, but Werner is very definitely the author of that word.

SCHWARTZ: That's right. Thank you.

GOODENOUGH: A question from Richard Miller: "Could you comment further on the fact that JOVIAL was always used to compile itself? Who was primarily responsible for this decision?"

SCHWARTZ: Oh, I think those of us who were on that original project out here on the West Coast—Erwin Book and Harvey Bratman, and others. The idea always was, for some reason, to compile the language in itself. It seemed quite logical at the time.

ERWIN BOOK: We also were kind of influenced by UNCOL [Universal Compiler Language] at the time and we thought to make a technology whereby we had one generator for all computers translating into an intermediate language. Then one could have different translators producing code for each different computer that we wanted—and that's the way the JOVIAL compilers are all built. The front end is reproduced very easily, and you just write a translator and that intermediate language is kind of half an UNCOL, but very limited.

GOODENOUGH: How much influence did FORTRAN have?

SCHWARTZ: FORTRAN really had, I would say, almost none on JOVIAL. It was really just getting started in those days. I think we had one fellow on the project who had used it.

The rest of us had read specs, but anything we did had really come from the IAL specs, plus our own invention.

GOODENOUGH: How many problems resulted from the many variations of declarations and the large number of descriptors in the language?

SCHWARTZ: I happened to read in preparing this material, much of the old documentation. (I got this from Chris Shaw, whom I mentioned as the guy who wrote much of the early documentation. He also collected every piece of paper that was written, informally or otherwise, and he donated it to me.) One of the documents was by people responsible for teaching and seeing that other people used the language. One of their remarks was that it was kind of difficult to teach the language, but they also said that they noticed—and these people were totally unbiased—that once people learned JOVIAL, they didn't have many problems. They remembered it, and they never had to go back to the documents. So, it seems that initial learning was the worst problem.

GOODENOUGH: The language uses items as its term of declaring an individual variable, which is different from the way FORTRAN or IAL uses REAL and INTEGER as its declaration mechanism. How did you come to make that particular choice?

SCHWARTZ: That was really based largely on the way the SAGE definitions were done (although SAGE had a machine language orientation). We added some things, but it was based on SAGE, which used the name "item" in Comm Pools and tables.

GOODENOUGH: Do you have any further comments on the name of the language, beyond what's in [pp 369–388] and in Jean Sammet's book?

SCHWARTZ: No, but I think if it had been called anything else, somebody else would probably have been chosen to be up here today. No, the preprint does give, I think, the fairly complete story on how the name came about.

GOODENOUGH: Thank you very much.

FULL TEXT OF ALL QUESTIONS SUBMITTED†

CHUCK BAKER

In JOVIAL data descriptions, some data attributes are bound at compile time (item type, length, etc.). Others are bound at execution time (table length). How was the choice of when to bind made? Would you change these choices now?

KEN DICKEY

Implicit in the design of the language is a high level of programming awareness (assembly language, data mixing, etc.). To what measure is this due to desire for flexibility, and what measure to time constraints?

† Jules Schwartz has annotated the full set of questions and provided answers to several that were not asked at the session.