New C/C++ and PL/I releases

Visda Vokhshoori
visdav@ca.ibm.com
z/OS V2.2 XL C/C++
z/OS V2.2 XL C/C++ availability

- Preview announce date, January 2015
- Availability announce date, July 2015
- General availability date, September 30, 2015
z/OS V2.2 XL C/C++ highlights

- Support for the new hardware
- Asm and hardware model support
- Two new high performance libraries
- Improved functionality

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Source: If applicable, describe source origin
Support for the new hardware
ARCH(11)

- To enable the compiler with the z13 feature we are introducing new sub options for ARCHITECTURE and TUNE options

- ARCH(11) will prompt the compiler to utilize the list of hardware instructions new in z13

- TUNE(11) will prompt the compiler to improve run time performance according to the micro-architecture characteristics of z13
Support for Load Halfword Immediate on Condition

- The new instructions LOCHI and LOCGHI are like LHI and LGHI except that the load depends on the conditional code and the mask in the instruction.

- The immediate value, as indicated in the name of the instruction, is halfword in size, so this applies only to values that fit in 16 bits.

- The compiler will exploit this under OPTimize and ARCH(11).
Support for Convert from|to Packed

- The new instructions
  - Convert from Packed
    - CDPT – Convert to long DFP
    - CXPT – Convert to extended DFP
  - Convert from Packed
    - CPDT – Convert from long DFP
    - CPXT – Convert from extended DFP

Under OPT and ARCH(11) the back-end utilizes these instructions where it finds the right pattern; these will improve the run-time performance as the DFP instructions are performed in registers and in general faster than packed decimal.
Support for the Vector Facility

- Vector programming support provides programmers direct access to SIMD instructions from the z13 Vector Facility for z/Architecture

- Language extensions based on the AltiVec Programming Interface specification with suitable changes and extensions
Support for the Vector Facility

- A new VECTOR option
- macro: __VEC__
- Compile options: -qARCH(11) -qVECTOR
- FLOAT(AFP(NOVOLATILE)) and TARGET(zOSV2R2) are assumed default
- Vector data types:
  - {vector, vector} {bool, signed, unsigned} {char, short, int, long long}
  - {vector, vector} double
- Various language extensions on the vector types for natural usage just like for the native types
  - Ex.
    - Assignment operator (=)
    - Address operator (&)
    - Pointer arithmetic
    - Unary operators (++,, −, +, −, ∼)
    - Binary operators (+, −, *, /, %, &, |, ^, <<, >>)
    - Relational operators (==, !~, <, >, <=, >=)
Support for the Vector Facility

- Comprehensive set of vector built-in functions for access and manipulation of individual vector elements
  - In the following high-level categories:
    - Arithmetic
    - Compare
    - Compare ranges
    - Find any element
    - Gather and scatter
    - Generate Mask
    - Isolate Zero
    - Load and Store
    - Logical
    - Merge
    - Pack and unpack
    - Replicate
    - Rotate and shift
    - Rounding and conversion
    - Test
    - All Predicates
    - Any Predicates
Support for the Vector Facility

Example:

```c
#include <builtins.h>
#include <stdio.h>
int main() {
    vector signed int a = {-1, 2, -3, 4}; // declare and initialize a vector with 4 signed integer elements
    vector signed int b = {-5, 6, -7, 8};
    vector signed int c, d; // declare vectors with 4 signed integer elements
    c = a + b; // Generates VAF
    d = vec_abs(c); // Generates VLPF

    printf("d[0] = %d\n",d[0]); // prints 6 -- d[0] extract the 1st element from the vector
    printf("d[1] = %d\n",d[1]); // prints 8

    return 0;
}
```
Support for the Vector Facility

- AutoSIMD compiler optimization
- Identifies source statements that are safe and profitable to be transformed into vector form, i.e. using single instruction that operates on multiple data

Example:

```c
unsigned int i, n, x;
unsigned int *a, *b;
for (i=0; i<n; ++i) {
    a[i] = a[i] + 4*b[i];
}
```

- AutoSIMD can process the loop 4x faster.
Support for the Vector Facility

- AutoSIMD compiler optimization is turned on by default when
  - HOT,FLOAT(AFP(NO Volatile)),ARCH(11)

- This optimization makes use of the z13 vector facility. Using the
  instructions that can operate on multiple data streams, introduced in
  z13 compiler can produce parallel code to improve throughput;
  more data processed in the same window of time

- Workloads that can benefit from SIMD include string processing-
  intensive workloads, security and cryptographic workloads, and
  mathematical modeling workloads
Initialization of 40 bytes starting at GPR4+2160 with 7 has been SIMDized, Reduced path length, more data processed
Support for the Vector Facility

- Vector programming references:
  - SIMD Business Analytics Acceleration on z Systems
  - z/OS V2.2 XL C/C++ Programming Guide
    Chapter 35: Using vector programming support]
  - AltiVec Technology Programming Interface Manual
asm and hardware model support
Ability to insert asm statements

- Clients have asked us to support HLASM statements for all C or C++ programs and not just with Metal C

- Now you can inline hardware instructions in your LE enabled C or C++ program using the __asm keyword

- Compiler output is program object, doesn't generate assembly source like MetalC

- Requires certain level of HLASM PTF
Ability to insert asm statements

- New options and sub-options

  - **ASM**: causes __asm, __asm__ to be statements
  - **Keyword(ASM)**: gives asm the same semantic as __asm
  - **ASMLIB**: specifies the macro libraries to be used when assembling the inline assembler source code; libraries will be concatenated

Example:
- `qASMLIB=A -qASMLIB=B`
  
  //ASMLIB DD DISP=SHR,DSN=A
  //              DD DISP=SHR,DSN=B

- New messages will be reported by the compiler under message CCN1148
Ability to insert asm statements

```c
#include <stdio.h>

int my_cipher(char* in, char* out, int* len, int parmBlock, int* mode) {
    /* Inline CIPHER Message */
    asm("REDO KMC %3,%0\n"
         " BRC 3,REDO\n" :"+XL:RP:e"(x),"+r"(*len),"+XL:NR:r1"(parmBlock),
         "+XL:RP:e"(out):"XL:NR:r0"(*mode):
    );
}
```

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Support for inline asm

- z/OS V2.2 XL C/C++ User’s Guide
  - New options ASM and ASMLIB

z/OS V2.2 XL C/C++ Language Reference
  - [Chapter 7
Mixing ARCH levels in one compile

- Before, you had to put code using different ARCH levels into separate functions – and you had to pay for the expense of calling the appropriate function

- You can now have code using different ARCH levels within one compilation unit
Mixing ARCH levels in one compile

- Now this code can be inlined with the new
  
  - #pragma arch_section(<architecture>)

- The pragma indicates the start of a section of the source intended for the machine indicated by <architecture>

- The compiler switches to architecture specified, and at the end the section switches back to the previous architecture
Identifying the hardware model and features

- Programs may need to check the machine model before doing some processing

- Three new builtins help with this:
  
  - builtin_cpu_init(void)

  - Runs the CPU detection code, and saves the CPU information in a compiler defined/managed buffer

  - Must be called at least once before either of the following is invoked
Identifying the hardware model and features

- `builtin_cpu_is(const char* cpumodel)`
  - Returns 1 if the CPU is of type `cpumodel` ("5", "6", ..., "11")

- `builtin_cpu_supports(const char* feature)`
  - Returns 1 if the CPU supports one of the features indicated

  - `feature` values are
Identifying the hardware model and features

```
xlc -c -qARCH=9 -o popcnt.o popcnt.c
xlc -c -qARCH=5 -o main.o main.c
xlc -o a.out popcnt.o main.o
./a.out
```

```
>cat main.c

// Counts bits that have the value of 1 in a byte
unsigned long myBytePopcount(char op)
{
    unsigned long count = 0;
    for (int i = 0; i < 8; i++) {
        if (((op & 1) == 1) {
            count++;
        }
        op >>= 1;
    }
    return count;
}
```
Identifying the hardware model and features

//main.c continued

#define arch9 2217
int main() {
    struct utsname ruon;
    uname(&runon);
    int archLevel = atoi(runon.machine);
    unsigned long output;
    unsigned long input = 55;

    //Check architecture level
    if (archLevel >= arch9) {
        output = callArch9Builtin(input);
    } else {
        output = myBytePopcount(input);
    }
    printf("%lu\n", output);
    return 0;
}
Identifying the hardware model and features

> cat popcnt.c
#include <builtins.h>
//Compiled with ARCH(9)
unsigned long callArch9Builtin(unsigned long op) {
  return __popcnt(op);
}
Using the \#pragma arch_section, and run-time check builtins the above can be
simplified to one file.

```c
#include <builtins.h>
unsigned long myPopCountOnByte(unsigned long op)
{
    unsigned int count = 0;
    for (int i = 0; i < 8; i++) {
        if ((op & 1) == 1) { count++;
    } op >>= 1;
}
return count;
}

int main()
{
    unsigned char input = 55;
    unsigned long output;
    __builtin_cpu_init();
    if (__builtin_cpu_supports("popcount")) {
        #pragma arch_section(9)
        {
            output = __popcnt(input)&0xFF;
        }
    } else {
        output = myPopCountOnByte(input);
    }
    printf("%lu\n", output);
    return 0;
}
```

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Identifying the hardware model and features

- **z/OS V2.2 Language Reference**
  [Chapter 18 #pragma arch_section](http://publibz.boulder.ibm.com/epubs/pdf/cbc1l210.pdf)

- **z/OS V2.2 Programming Guide**
  [Chapter 34 __builtin_cpu_xxxx](http://publibz.boulder.ibm.com/epubs/pdf/cbc1p210.pdf)
New high performance libraries
New high performance math library

- MASS (Mathematical Acceleration Sub-System) library
- A comprehensive set of elementary/special mathematical functions (e.g. exp, log, sin, etc.) tuned for high performance on zEC12 and z13
- 3 kinds of libraries:
  - 59 scalar functions
    - Easiest to use in existing code since names match existing runtime library functions
  - 77 vector functions
    - Generally provides the highest performance, provided vector_length is sufficient (approximately >2 to >10 depending on the function)
  - 8 SIMD (z13 only) functions
    - Convenient for code written to use vector datatypes and built-in functions
- Single- and Double-precision FP, in IEEE
New high performance math library

MASS archives /usr/lpp/cbclib/lib:
libmass.arch10.a       libmassv.arch10.a       libmass.arch11.a
libmassv.arch11.a       libmass_simd.arch11.a

MASS header files /usr/include:
mass.h        mass_simd.h        massv.h

Mass in batch mode:
MASS archives:
CBC.SCCNM10       scalar MASS library overlap with LE
CBC.SCCNN10       scalar and vector MASS library not overlap with LE
CBC.SCCNM11       single precision MASS ARCH(11) library
CBC.SCCNN11       double precision MASS ARCH(11) library
MASS Header files:
CEE.SCEEH.H

Compile Options:
FLOAT(IEEE)
ARCHITECTURE(10) -the minimum for zEC12/zBC12
ARCHITECTURE(11) -the minimum for the z13
VECTOR -if using the mass_simd
NOEXH -if using C++
Do not change the rounding mode from the default value: ROUND(N)
Include the appropriate header files
If using scala MASS, include both mass.h and math.h
If using vector MASS, include massv.h
If using SIMD MASS, include mass_simd.h

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MASS performance

- z/OS MASS (Mathematical Acceleration Subsystem) vector functions on z13 demonstrate **up to 2.9x higher throughput** than the corresponding z/OS V2.1 XL C/C++ runtime library math functions on zEC12.

- A key subset of MASS vector functions are heavily used in Analytics and are accelerated using SIMD instructions. These functions demonstrate **up to 6.8x higher throughput** than the corresponding z/OS V2.1 XL C/C++ runtime library math functions on zEC12.

Disclaimer
This claim is based on results from internal lab measurements. A subset of the MASS vector functions is accelerated using SIMD instructions on z13. The SIMD benefit is demonstrated using this subset. The performance improvements achieved will vary depending on the workload and other factors.
New high performance linear algebra library

- ATLAS (Automatically Tuned Linear Algebra Software) library
- A high-performance versions of all the BLAS (basic linear algebra subprograms) routines, and a subset of the LAPACK (linear algebra package) routines
- Tuned for high performance on zEC12/zBC12 and z13
- Both single and multi-threaded versions available, with IEEE floating point
- Supplied libraries
  - ATLAS main libraries
    - ATLAS specific variants of the BLAS, CBLAS, and LAPACK routines
  - CBLAS libraries
    - C interface versions of the BLAS routines
  - LAPACK libraries
    - C interface versions of the LAPACK routines
  - Fortran BLAS libraries
    - Fortran 77 interface versions of the BLAS routines
- Supports 31-bit C linkage, 31-bit XPLINK, and 64-bit XPLINK
New high performance linear algebra library

- ATLAS is provided on USS only
- Library & header file location:
  - Library: /usr/lpp/cbclib/lib/atlas/
  - Header: /usr/lpp/cbclib/include/atlas/

- Compile options requirement
  - FLOAT(IEEE)
  - ROUND(N) - default rounding for FLOAT(IEEE)
  - ARCHITECTURE(10) - the minimum required ARCH level
  - ARCHITECTURE(11) - required to enable vector functionality
  - VECTOR - required to enable vector functionality

- More information can be found:
  - z/OS V2.2 Programming Guide [Chapter 43](http://publibz.boulder.ibm.com/epubs/pdf/cbc1p210.pdf)
ATLAS performance

- A key subset of z/OS ATLAS 3.10.0 (Automatically Tuned Linear Algebra Software) double precision functions on z13 demonstrate up to 44% higher throughput than the corresponding functions on zEC12.

- Selected key z/OS ATLAS 3.10.0 (Automatically Tuned Linear Algebra Software) functions are accelerated using SIMD instructions. These functions demonstrate up to 80% higher throughput on z13 than the corresponding functions on zEC12.

Disclaimer:
This claim is based on results from internal lab measurements. The double precision function improvement is derived from comparisons of a select set of commonly used z/OS ATLAS 3.10.0 functions executing on z13 to the equivalent functions executing on zEC12. A subset of these functions is accelerated using SIMD instructions on z13. The SIMD benefit is demonstrated using this subset. The performance improvements achieved will vary depending on the workload and other factors.

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Increased functionality
Improved make

- 'make' dependency file generation through -M did not include non-existent headers or allow named targets
- New make options address these and similar concerns:
  - -MT allows setting the dependent target name
  - -MQ is -MT but also escapes 'make' special characters for easier dependency file usage
  - -MG allows missing header files to be included in the dependency list
  - The -qmakedep=pponly suboption will run the include preprocessing only
    - A dependency file will be generated
    - But no object code will be generated

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Expanded user-reserved space on the Metal C stack

- This is an enhancement to an existing feature
- The option DSAUSER, available only with MetalC, allows the user to reserve a pointer on the stack
- However, the user may want to leave more space on the stack

- DSAUSER has been enhanced to allow you to specify how much space to reserve on the stack

  -xlc -qDSAUSER=12

- This will reserve a space equal to the size of 12 words on the stack
Eliminating a null pointer check

- The C++11 ANSI Standard requires
  – checking the pointer returned from the placement new operator
  – and performing the initialization only when the pointer is not null

- The check for null pointer returned from other operators new and new[] is not required but performed

- New sub-option `LANGLVL (NOCHECKPLACEMENTNEW)` will remove the check of the pointer returned by the placement new operator

  – And can thus speed up the program by eliminating unnecessary null pointer checks

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Improvements to dbgld utility

- A new option has been added to prompt dbgld to capture source files without executable statement, e.g. variable declarations
  - `dbgld -cf a.out`
  - JCL CAPSRC(FULL)
Improvements to c89 utility

- Enable c89 to pass environment variables to the binder
- Accept mixed case, longer than 9, and hyphenated symbol or entry point name to be specified to SYMTRACE, and EP binder options

```c
int one_TWO_three() { return 1+2+3; }
export IEWBIND_OPTIONS="SYMTRACE=one_TWO_three"
c89 -Wl,'MSGLEVEL=0' t.c >o 2>&1
grep one_TWO_three o
IEW2420I A61B SYMTRACE: SYMBOL one_TWO_three IS DEFINED IN SECTION $PRIV000010
IEW2422I A61D SYMTRACE: SYMBOL one_TWO_three DEFINITION ORIGINALLY CAME FROM
```

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Enterprise PL/I 4.5

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Enterprise PL/I 4.5 highlights

- Improved performance
- Enhanced middleware support
- Increased string length limit
- Introduced support for JSON
- Increased functionality
- Added features to enforce code quality
- Satisfied 28 RFE's
Improved performance
ARCH(11)

Under ARCH(11), the compiler will exploit
  - The new Load Halfword Immediate on Condition instruction
  - The new vector hardware instructions (and registers)

The latter significantly improves the performance of the code generated for (MEM)SEARCH and (MEM)VERIFY of CHAR and WIDECHAR strings.

The vector facility consists of:
  - Support instructions
  - Integer instructions
  - String instructions
  - Float instructions
ARCH(11)

- PL/I currently exploits only the support and string instructions

- In particular, to implement SEARCH and VERIFY, these vector instructions are very useful

  - find_any_element_equal
  - find_any_element_not_equal
  - string_range_compare
**ARCH(11)**

- For example, this simple code that tests if a UTF-16 string is numeric

```plaintext
wnumb: proc( s );

  dcl s  wchar(*) var;
  dcl n  wchar value( '0123456789' );
  dcl sx fixed bin(31);

  sx = verify( s, n ); if sx > 0 then ...
```

- Is done with an expensive library call with ARCH <= 10
**ARCH(11)**

With ARCH(11), the vector instruction facility is used to inline it as

<table>
<thead>
<tr>
<th>Opcode</th>
<th>Value1</th>
<th>Value2</th>
<th>Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>E700</td>
<td>E000</td>
<td>0006</td>
<td>VL</td>
</tr>
<tr>
<td>E740</td>
<td>E010</td>
<td>0006</td>
<td>VL</td>
</tr>
<tr>
<td>0180</td>
<td>408A</td>
<td></td>
<td>VSTRC(v2,v2,v0,v4,b'0001',b'1000')</td>
</tr>
<tr>
<td>E725</td>
<td>E000</td>
<td>0037</td>
<td>VLL</td>
</tr>
<tr>
<td>E722</td>
<td>0180</td>
<td>408A</td>
<td>VSTRC(v2,v2,v0,v4,b'0001',b'1000')</td>
</tr>
<tr>
<td>E7E2</td>
<td>0001</td>
<td>2021</td>
<td>VLGV</td>
</tr>
<tr>
<td>E65E</td>
<td>000D</td>
<td>2076</td>
<td>CRJH</td>
</tr>
<tr>
<td>A74A</td>
<td>FFF0</td>
<td></td>
<td>AHI</td>
</tr>
</tbody>
</table>
Other performance improvements

- Much faster code is now generated for MOD and REM of large FIXED DEC
- Previously, calls to a library routine were used for this
- Now inline code using DFP makes the calculation much faster
- ARCH(11) is not required for this
Other performance improvements

- ARCH(11) not required is also not required for improvements to
- INLIST of CHAR(1)
- BETWEEN for CHAR(1) and WCHAR(1)
- SEARCH and VERIFY of WCHAR(1)
Other performance improvements

- A SELECT statement of the form

  ```sql
  select( x ); when( '..' ) ..
  when( '..' ) ..
  ...
  ```

- Was turned into a (fast) branch table if x was CHAR(1) and into a (slow) series of string compares if x had length > 1

- Now it will also be turned into a branch table if x is CHAR(2) or CHAR(4)
Other performance improvements

- One user has some code with this SELECT statement

```
SELECT(PLAUS.PLZ); WHEN('0000') ...
WHEN('9999') ...
WHEN('1000') ...
WHEN('1004') ...
```

- With more than 2500 WHEN clauses

- With 4.4, it takes 90 seconds to compile under OPT(2)
- With 4.5, it takes 5 seconds, and the generated code is much better, too!
EXEC CICS statements

- The code generated for every EXEC CICS statement consists of a call to a CICS entry point with a first parameter that is an unprintable character string often longer than 100 bytes.

- This string encodes for CICS what the statement is requesting.

- Since the call appears to be an ordinary call to the compiler, it allocates a temporary on the stack and generates a MVC instruction to copy the 100+ bytes from the constant area to that temporary.
EXEC CICS statements

- The 4.5 compiler now marks the first parameter of the CICS entry point with the INONLY attribute.
- This eliminates the allocation of the temporary on the stack and the (slow) MVC instruction to copy to it.
- This means the code will run faster, and your DSA will be smaller too.
Enhanced middleware support
Previously, if you wanted to use indicator variables with a structure in an EXEC SQL statement, you had to name each element of the structure and an associated indicator variable. For example, given

```sql
dcl 1 h3, 2 a fixed dec, 2 b fixed dec, ..., 2 z fixed dec;
```

You had to code a matching structure and then name everything

```sql
dcl 1 in3, 2 a fixed bin(15), 2 b fixed bin(15), ..., 2 z fixed dec; exec
sql insert into mytable
values( :h3.a:in3.a, :h3.b:in3.b, ..., :h3.z:in3.z );
```
Structures as indicator variables

- Not fun and not easy to maintain or enhance. But now you can use a structure as indicator variable. So, given

  ```
  dcl 1 h3, 2 a fixed dec, 2 b fixed dec, ..., 2 z fixed dec;
  ```

  ```
  dcl 1 in3, 2 a fixed bin(15), 2 b fixed bin(15), ..., 2 z fixed dec; exec
  ```

  ```
  sql insert into mytable

  .   values( :h3:in3 );
  ```
But it gets better: with the new INDFOR attribute (it's like LIKE except the copied names all get the FIXED BIN(15) attribute), the matching indicator structure is easy to declare. So, given

```
dcl 1 h3, 2 a fixed dec, 2 b fixed dec, ..., 2 z fixed dec;
```

you can use INDFOR and code simply

```
dcl 1 in3 indfor h3;
exec sql insert into mytable
values( :h3:in3 );
```
Structures as indicator variables

- And multi-row fetch (and dimacross) work here, too! So, given

  dcl 1 h3(3) dimacross, 2 a fixed dec, 2 b fixed dec, ..., 2 z fixed dec;

- you can use INDFOR and code the very simple

  dcl 1 in3(3) dimacross indfor h3; exec sql
  insert into mytable
    values( :h3:in3 );
Named constants as host variables

- You can now use named constants as SQL host variables if
  - DB2 allows a simple, unnamed constant at that place in the EXEC SQL statement
  - And
    - the named constant has either the attribute
      - CHARACTER, in which case its VALUE attribute must specify a character string
      - or
      - FIXED, in which case its VALUE attribute must specify a decimal number or an expression that can be reduced to an integer constant
Statement validation

- Previously, when the SQL preprocessor scanned an EXEC SQL statement, it would report only the first error in the statement

- Now, it will report all the errors in every EXEC SQL statement
Using the new SQL preprocessor option (NO)CODEPAGE, you can control the preprocessor's use of the compiler's CODEPAGE option when it sets the CCSID of a host character variable.

- When CODEPAGE is in effect, the compiler's CODEPAGE option is always used as the CCSID for SQL host variables of character type.

- When NOCODEPAGE is in effect, the compiler's CODEPAGE option is used as the CCSID for SQL host variables of character type only if the SQL preprocessor option NOCCSID0 is also in effect.

- NOCODEPAGE is the default for compatibility with previous releases.
Using the new SQL preprocessor option (NO)WARNDECP, you can control whether the SQL preprocessor issue a warning message if it uses the DB2-provided DSNHDECP module.

- PP(SQL('WARNDECP')) matches what the previous releases did.

- But NOWARNDECP is now the default (since this message is almost meaningless to most users and hence is just distracting noise).
Less noise from the SQL preprocessor

- Message DSNH4760I is now suppressed – this shows up as

  IBM3024I I ...... DSNH4760I DSNHPSRV  The DB2 SQL Coprocessor is using the level 2 interface under DB2 V9

- This is almost always uninteresting

- This has been removed for 4.3 as well as 4.4
Increased string length limit
From 32K to 128M

- Previously no string could be 32K or longer, and VARYING strings had only a 2-byte length prefix

- The new VARYING4 attribute will let you declare strings as having a 4-byte length prefix

- The new STRING suboption of the LIMITS option will let you set the threshold for string lengths to be 32K, 512K, 8M, or 128M
From 32K to 128M

- The maximum length is one less than the threshold
- The default is 32K
- The threshold values may be specified using K or M suffices or as decimal numbers, i.e. as 32K or 32768 or as 128M or 134217727
- But ...
From 32K to 128M

- A threshold bigger than 32K may be specified only if the CMPAT(V3) option is also in effect – because an expanded string descriptor is needed.

- And mixtures of code compiled with CMPAT(V2) and CMPAT(V3) face the same restrictions as mixtures of code compiled with CMPAT(V1) and CMPAT(V2) faced 30-years ago.

- Fwiw, the new VARYING4 attribute may be used with CMPAT(V2) - but then the length must still be less than 32K.
Long string considerations

- Specifying LIMITS( STRING(n) ) where n > 32K may also greatly increase the amount of stack storage used by your code.

- For example, in PUT LIST( A || B ) where A and B are CHAR(*) VARYING4, the compiler will allocate a temporary on the stack equal to the maximum string size – so under LIMITS(STRING(128M)) this would be 128M off the stack!!

- The MAXTEMP compiler option will alert you to such statements.
Long string considerations

- The STRING limit applies to all kinds of strings: BIT, CHAR, GRAPHIC and WIDECHAR

- The VARYING4 attribute is also supported for all kinds of strings

- ALIGNED VARYING strings are halfword-aligned – ALIGNED VARYING4 strings will be fullword-aligned
The descriptors generated under CMPAT(V3) are different than those generated under CMPAT(V2) – and not just for strings.

- The offsets in structure descriptors and the bounds etc in array descriptors are all 8-byte integers.
Support for JSON
JSON overview

- A series of built-in functions provide the ability to
  - Generate JSON text
  - Parse JSON text
  - Validate JSON text

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JSON generation

- All JSON written out will be in UTF-8 with the compiler and library handling any necessary conversions from EBCDIC

- A series of "put" functions are provided and all have a buffer address and buffer length as their first 2 arguments, and all return the number of bytes written

- Attempts to write variables containing data types incompatible with JSON will be flagged at compile time

- Escaped characters will be created as needed
JSON parsing

- All JSON to be parsed must be in UTF-8 with the compiler and library handling any necessary conversions to EBCDIC

- A series of “get” functions are provided and all have a buffer address and buffer length as their first 2 arguments, and all return the number of bytes read

- Attempts to read variables containing data types incompatible with JSON will be flagged at compile time

- Whitespace characters will be skipped over when found
For example, suppose we have this sample JSON text:

```json
{ "passes" : 3, "data" : [
    {
        "name" : "Mather",  "elevation" : 12100
    },
    {
        "name" : "Pinchot",  "elevation" : 12130
    },
    {
        "name" : "Glenn",  "elevation" : 11940
    }
]}

And that it is in a buffer at address p and of length n.
If we had a corresponding PL/I structure

```pli

dcl

  1 info

  2 passes fixed bin(31), 2 data(3),

  3 name char(20) varying,

  3 elevation fixed bin(31);
```

Then `jsonGetValue( p, n, info )` will by itself fill in the whole structure

This one simple function call would do all the work for you
But if we did not know how many data instances we would get, our PL/I structure might instead look like

dcl
  1 info based(q)
    2 count fixed bin(31),
    2 data( passes refer(count) ),
    3 name char(20) varying,
    3 elevation fixed bin(31);

And it would have to be dynamically allocated – but this is still easy:
Four built-in references would suffice:

```c
rd = jsonGetObjectStart(p,n); /* read over { */
rd = jsonGetMember(p+rd,n-rd,passes); /* read “passes”:3 and assign it */
allocate info;
rd = jsonGetComma(p+rd,n-rd); /* read over , */
rd = jsonGetValue(p+rd,n-rd,info.data); /* read “data” ... and assign it */
```

And this works, of course, no matter how much whitespace is present.
Increased functionality
INLIST

- This built-in function is useful in determining if a value belongs to a set of values and allows you to put a SELECT in the middle of an IF

- It requires a minimum of 3 arguments and accepts a maximum of 64

- INLIST( x, a, b, c, … ) is equivalent to ( x = a ) | ( x = b ) | ( x = c ) …

- All the arguments must have computational type

- The compiler will optimize this when possible
INLIST

- The arguments can be numbers, strings, or arbitrary expressions
  
  
  - if inlist( uppercase(stadt), ‘BERLIN’, ‘BERN’, ‘ROM’, ‘WIEN’ ) then
  
  - if inlist( x, 2, y, 7, z ) then
  
  - if inlist( b, b1 | b2, ‘1100’b, b3 & b4 ) then

These would all be converted to a short-circuited series of compares.
But if the first argument is “nice” and the rest are all similar values, then the compiler will turn the inlist reference into a branch table. For example,

```
   inlist( x, 2, 3, 5, 7, 11, 13, 17, 19 )
```

would become a branch table if \( x \) is FIXED BIN(\( p,0 \)) with \( p \leq 31 \) or if \( X \) is FIXED DEC(\( p,0 \)) with \( p \leq 9 \)

The values 2, 3, 5, etc don’t have to be literals – they can be named constants (VALUEs) or restricted expressions

And if all are CHAR(1), a simple table look-up is generated
• Branch tables would also be built if

  ▶ X is BIT\(n\) with \(1 \leq n \leq 16\) and the other arguments are bit constants

  ▶ X is CHAR(1) and the other arguments are CHAR(1) constants

• Again the second and subsequent arguments don’t have to be literals – they can be named constants (VALUEs) or restricted expressions
BETWEEN

- This built-in function is useful in determining if a value is in an interval
- It requires exactly 3 arguments
- BETWEEN( x, a, b ) is equivalent to ( x >= a ) & ( x <= b )
- All the arguments must be ordinals or have real numeric type
- The compiler will optimize this when possible
  - For example, if x, a, and b are all FIXED BIN(p,0) with p <= 31, then the compiler will turn BETWEEN( x, a, b ) into one comparison (not two!)
  - OORDINAL, CHAR(1), and WCHAR(1) are optimized in the same way

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NULLENTRY

- This built-in function allows you to initialize an entry variable with a null value – including static variables

- Dcl function_pointer limited entry static init(nullentry());

- You can also use it to test an entry value to see if it is null
These built-in subroutiness will generate the corresponding instructions.

- PLISTCK( x ) sets an UNSIGNED FIXED BIN(64)
- PLISTCKE( x ) sets a CHAR(16) NONVARYING
- PLISTCKF( x ) sets an UNSIGNED FIXED BIN(64)

Each returns a FIXED BIN(31) that is the condition code set by the corresponding hardware instruction.
SMFTOJULIAN and JULIANTOSMF

- These built-in functions convert between the Julian and SMF date formats
  - SMFTOJULIAN(d) converts a CHAR(4) SMF date to a CHAR(7) YYYDDDD
  - JULIANTOSMF(d) converts a CHAR(7) YYYDDDD to a CHAR(4) SMF
- No error checking is done at run-time for these functions – the conversions are done in-line, and the input data must be valid
These built-in functions now allow the event function pointers to be null.

- When null, the event will not be called.
- This allows you to write smaller, faster XML parsing code.
- It requires a library PTF (but not the 4.5 compiler).
This statement allows you to reset a variable with its INITIAL values.

The variable must be level-one, unsubscripted with storage class:

- AUTOMATIC
- BASED
- CONTROLLED
- STATIC
This preprocessor built-in function returns the number of bytes needed to hold the largest array bound

- Under CMPAT(V1), SYSDIMSIZEx returns 2
- Under CMPAT(V2), SYSDIMSIZEx returns 4
- Under CMPAT(V3), SYSDIMSIZEx returns 8
SYSPOINTERSIZE and SYSOFFSETSIZE

- These preprocessor built-in functions return the size (in bytes) of a POINTER and an OFFSET.

- As of now, they always return a 4.

- But when 64-bit code is supported they could return an 8, and they will be useful in writing code that will compile and run correctly both in 32-bit and in 64-bit mode.
SYSPOINTERSIZE and SYSOFFSETSIZE

- For example, you could use syspointersize to declare C's malloc

  %if syspointersize = 8 %then %do;
  define alias size_t fixed bin(63);
  %end; %else %do;
  define alias size_t fixed bin(31);
  %end;

  dcl malloc ext('malloc')
  entry( type size_t byvalue )
  returns( byvalue pointer )
  options( linkage(optlink) nodescriptor );

- And this would be correct for 32- and 64-bit
XML compiler option

- This option now supports an XMLATTR suboption with suboptions of APOSTROPHE or QUOTE

- It determines whether XML attributes are enclosed as '…' or “....”

- It requires a library PTF (as well as the 4.5 compiler)
Quotes in pictures

- The apostrophe symbol is now accepted in PICTURE specifications
- With the same usage as the comma or period symbol
- This requires only a library PTF
Added features to enforce code quality
Previously RULES(NOLAXRETURN) caused the compiler to generate code to raise the ERROR condition if

- RETURN; was hit in a PROC with the RETURNS attribute
- RETURN(...); was hit it a PROC without the RETURNS attribute

Now the options has been enhanced so that the compiler will raise the ERROR condition if code falls through to the END statement in a PROC with the RETURNS attribute
This makes it much easier to detect the lack of the desired statement after the else in this segment of real customer code:

```
func: proc( ... ) returns( fixed bin(31) );

... 

if flags = ''b then; else
    return(0);
end;
```

This problem would probably now be resolved within minutes rather than days it took to resolve it previously via the PMR process.
The new MAXBRANCH compiler option lets you find blocks (PROCEDUREs and BEGIN-blocks) that are perhaps too complex. More precisely, it flags any block that has too many conditional branches.

- A statement of the form "if a then ...; else ..." adds 1 to the total number of branches in its containing block, and a statement of the form "if a = 0 | b = 0 then ..." adds 2.

- SELECT statements and conditional DO loops also to the total.

- The default is MAXBRANCH(2000)
The new NONASSIGNABLE suboption of the DEFAULT compiler option now supports INONLY and STATIC as suboptions.

- NONASSIGNABLE(INONLY) specifies that parameters declared with the INONLY attribute are given the NONASSIGNABLE attribute.
- NONASSIGNABLE(STATIC) specifies that STATIC variables are given the NONASSIGNABLE attribute.
- These suboptions have no effect on variables that are explicitly given the ASSIGNABLE or NONASSIGNABLE attribute or on structure members that have inherited the ASSIGNABLE or NONASSIGNABLE attribute from a parent where it was explicitly specified.
BYVALUE parameters are given the INONLY attribute after the resolution of the (NON)ASSIGNABLE attribute, and hence the NONASSIGNABLE(INONLY) suboption has no effect on BYVALUE parameters (unless, of course, they are explicitly given the INONLY attribute).

To specify that both STATIC and INONLY variables are to be given the NONASSIGNABLE attribute, then you must specify the suboption NONASSIGNABLE( STATIC INONLY ).

The NONASSIGNABLE attribute may be specified without any suboptions, in which case it has the same meaning as in previous releases, namely NONASSIGNABLE( STATIC ).
The NOLAXQUAL suboption of RULES now accepts another choice of suboptions:

- Under the default NOLAXQUAL(ALL), the compiler will flag all violations of the qualifications rules (either STRICT or LOOSE)

- But under NOLAXQUAL(FORCE), the compiler will flag only those violations when the element belongs to a structure with the new FORCE(NOLAXQUAL) attribute

- This gives you the ability to enforce mandatory qualification on a structure-by-structure basis
 RULES(NOLAXNESTED and NOPADDING)

- The new ALL | SOURCE suboptions to the RULES(NOLAXNESTED) and RULES(NOPADDING) compiler options provide finer control over when the compiler flags questionable coding
  - Under ALL, all violations are flagged
  - Under SOURCE, only those violations that occur in the primary source file are flagged
  - This matches what is already supported for RULES(NOUNREF)
  - For each of these options, ALL is the default