11026 C30

Advanced Features in MPLAB® C30

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Prerequisites/Goals

You should be familiar with Microchip's 16-bit architecture and have had some basic introduction to MPLAB® C30

We will provide some advanced information that will help you get what you need from the tools to use the advanced features of the architecture

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Objectives

- **Today you will learn about…**
  - Mixing C and assembly
  - Allocating many types of memory
  - Accessing data in Flash
  - CodeGuard™ Security Support

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Agenda

- **Mixing C & Assembly**
  - Overview
  - Calling assembly functions from C
  - Inline Assembly
- **Memory Models**
- **Program Space Visibility**
- **CodeGuard™ Security Support**

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Mixing C and Assembly

Reasons to use assembly:

- **Architecture requirements:**
  - precise timing
  - to generate specific code sequences
  - to generate instructions not supported by compiler

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Mixing C and Assembly

- **Writing complete assembly function**
  - call an assembly routine from C

    or call a C routine from assembly
  - key topics:
    - **calling conventions and register usage**
    - **stack usage**
- **Writing inline assembly**
  - how to reference C variables

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Mixing C and Assembly

Which kind should I use?

assembly function	inline asm
• long sequence	• short sequence
• call cost is minor	• call cost too great
• limited references to C data	• refers to C data
• control flow allowed	• no control flow

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External Asm Functions

- **MPLAB® ASM30 reference: DS51317**
  - assembler syntax
- **dsPIC30F/33F Programmer's Reference Manual: DS70157**
  - assembly language instruction set
- **MPLAB C30 User's Guide: DS51284**
  - calling convention, chapter 4

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External Asm Functions

- **Basic form of an assembly file:**

```
.section my_code, code
.global _myfunction
; myfunction is externally visible
; and starts here!
_myfunction:
 clr w0
 ; and so on
```

External Asm Functions

- How can I call it from C?
- First, declare the function `extern`

```
extern void myfunction(void);
```

- Then call it as a normal function!

```
void main(void) {
   myfunction();
   /* and so on */
}
```

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Calling Convention

- **Parameters passed in W0 to W7**
  - parameters are placed in the first *properly aligned* register(s)
  - starting from the left-most parameter
  - if there are enough registers to hold the entire object
- **Additional parameters are pushed onto the stack**
  - right-most unallocated parameter is pushed *first*

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Calling Convention

- **Values returned in W0**
  - and W1 to W3 if required
- **A called function can use W0-W7 without preserving them**
  - Upon return to the calling function, these registers need not hold the same values
  - W8-W15 **must** be preserved
- **There are no unused registers**
- **ISRs – preserve all used registers!**

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Register Alignments

- **What does *properly aligned* mean?**

Type	registers required	alignment
char	1	none
short	1	none
int	1	none
data pointer	1	none
long	2	even
float	2	even
long long	4	divisible by 4
long double	4	divisible by 4
structure	1 per 2 bytes	none

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Inline Assembly

- **MPLAB® C30 User's Guide: DS51284**
  – syntax and guidelines, chapter 8

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Inline Assembly

- **Two forms available**
- ***Simple:***

```
asm("assembly text");
```

- ***Complex:***

```
asm( "template" :
    "format"(variable),... :
    "format"(variable),... :
    "clobbers");
```

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Inline Assembly

- **The complex version is, well, complex! Why use it?**
  - if the assembly instruction **uses any** register
  - if you need to access any C variable
- **Failure to understand this will cause unpredictable results**
  - programs will fail under changing circumstances

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Inline Assembly

- **What is the format string for?**
  - identifies the kind of operand needed
  - constrains the variable to the correct format
  - Examples, "r" – a register or
    "m" – a memory address

```
asm( "template" :
   "format"(variable),... :
   "format"(variable),... :
   "clobbers");
```

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Inline Assembly

- **A format string can include extra information, such as:**
  - read only operand
  - write only operand
- **Output (write) operands are listed 1st**

```
asm( "template" :
    "format"(variable),... :// outputs
    "format"(variable),... :// inputs
    "clobbers");
```

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Inline Assembly

- **What are clobbers?**
  - Some instructions will implicitly modify the value stored in a register
    - **the compiler needs to know when this happens**

```
asm( "template" :
   "format"(variable),... :
   "format"(variable),... :
   "clobbers");
```

Inline Assembly

- **What is the template?**
  - mostly it is assembler text
  - special symbols **`%0,%1,...%n`** can refer to arguments
    - **these can be modified `%d1`**

```
asm( "template" :
   "format"(variable),... :
   "format"(variable),... :
   "clobbers");
```

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Inline Assembly

- **Examples:**

```
asm ( “add %1, #%2, %0” :
        “=r”(result)       :
        “r”(input), “i”(CONSTANT) );

asm ( “mul.su %1, #%2, %0 :
        “=r”(result)          :
        “r”(input), “i”(CONSTANT) );
```

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Inline Assembly

```
#define CONSTANT 10
int add(int input) {
  int result;
  asm ( “add %1, #%2, %0” :
        “=r”(result)      :
        “r”(input), “i”(CONSTANT) );
  return result;
}
```

Inline Assembly

```
#define CONSTANT 10
long mulsu(int input) {
  long result;
  asm ( “mul.su %1, #%2, %0” :
        “=r”(result)          :
        “r”(input), “i”(CONSTANT) );
  return result;
}
```

Agenda

- **Mixing C & Assembly**
- **Memory Models**
  - 16-bit architecture review
  - Application use
- **Program Space Visibility**
- **CodeGuard™ Security Support**

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Memory Architecture

- **Harvard Architecture**
  - DATA RAM
    - **16 bits wide**
    - **16 bits of address**
  - PROGRAM Flash
    - **24 bits wide**
    - **23 bits of address**

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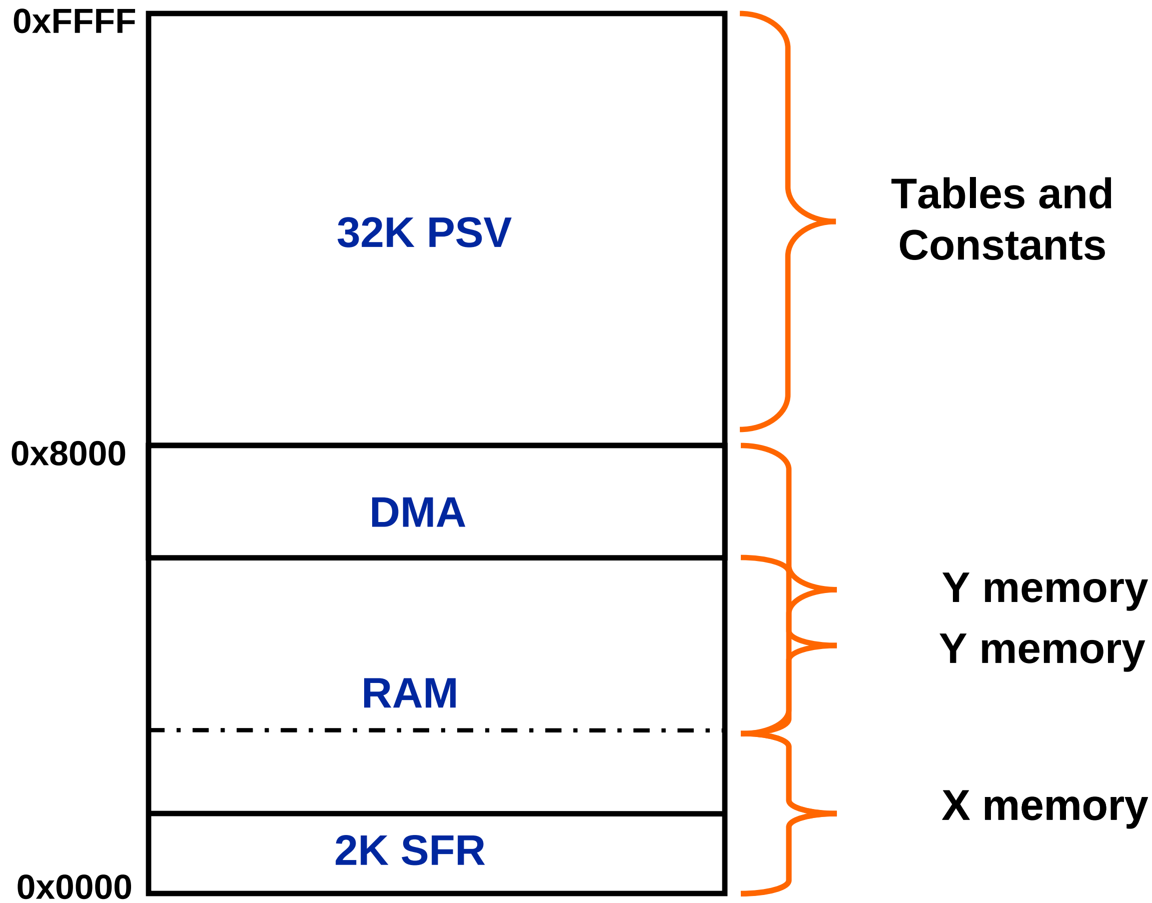
Data Space Memory Map



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Program Space Memory

- **Stores executable instructions**
- **Device configuration fuses**
- **EEPROM Data**
- **Can store DATA also**
  - accessed via Program Space Visibility (PSV) window
  - accessed via specialized read instructions
- **Reprogrammable during execution**

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Application Use

- **Why care about memory layout?**
  - Different data memory requirements:
    - **DSP uses X Memory or Y Memory**
    - **DMA uses the DMA memory**
  - Some instruction sequences are more efficient!
    - **Direct ALU access to near memory**
    - **Relative branches/calls faster**

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Application Use

- **It's *easy* to constrain memory!**
- **C Global memory models**
  - via command-line options or IDE radio buttons
- **Individual memory settings**
  - via C or assembly attributes

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Memory Models

- **MPLAB® ASM30 reference: DS51317**
  - assembler section directive, chapter 6.3
- **dsPIC30F Family Reference: DS70046**
  - hardware information
- **MPLAB C30 User's Guide: DS51284**
  - attributes, chapter 2.3
  - memory models, chapters 4.6,4.7,4.8

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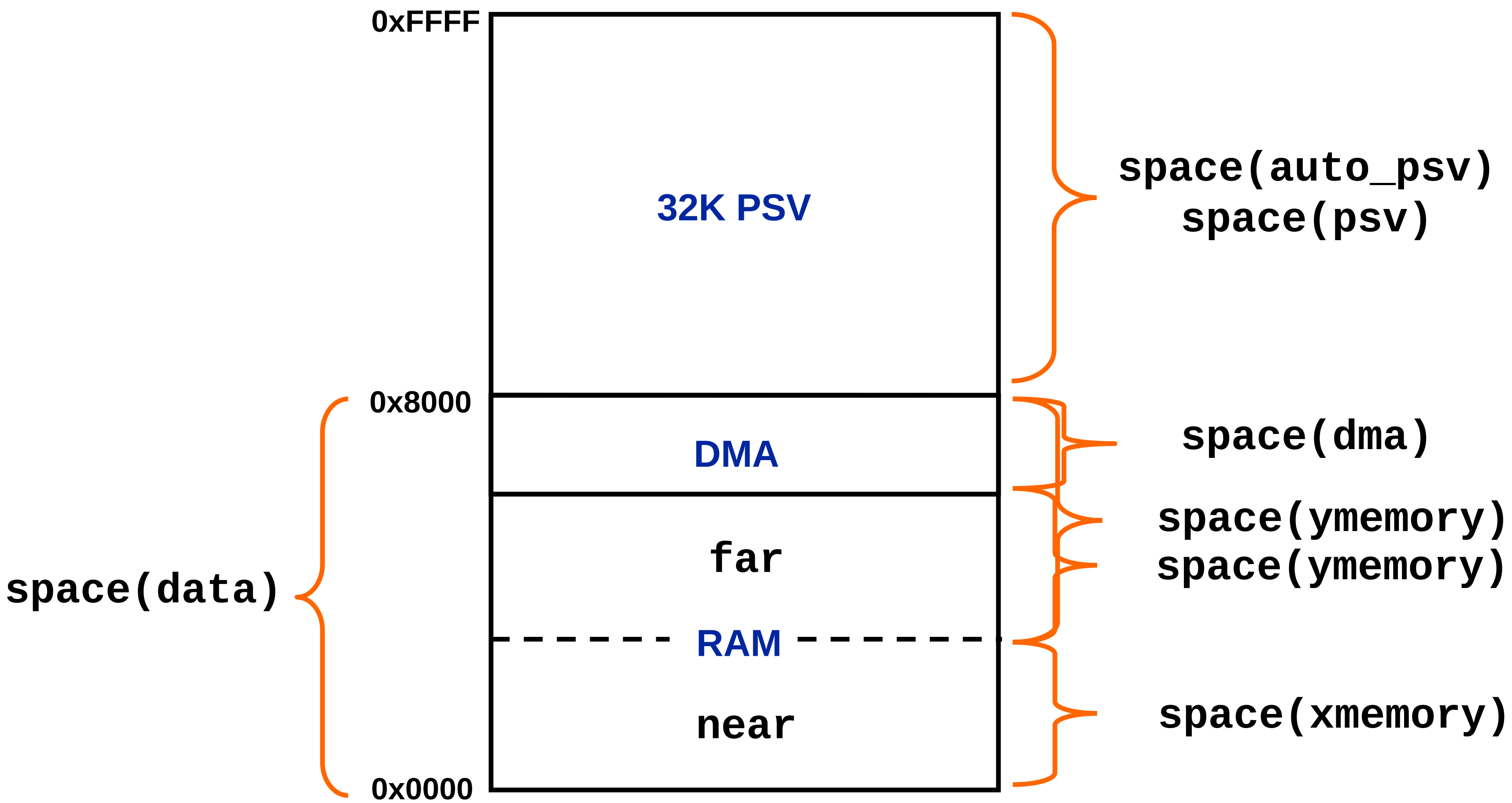
Data Space Memory Map



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Default Memory Models

- **Data locations**

  Scalar variables: near data

  Aggregate variables: near data

  Constants: automatic PSV

- **Functions**

  Small code model by default

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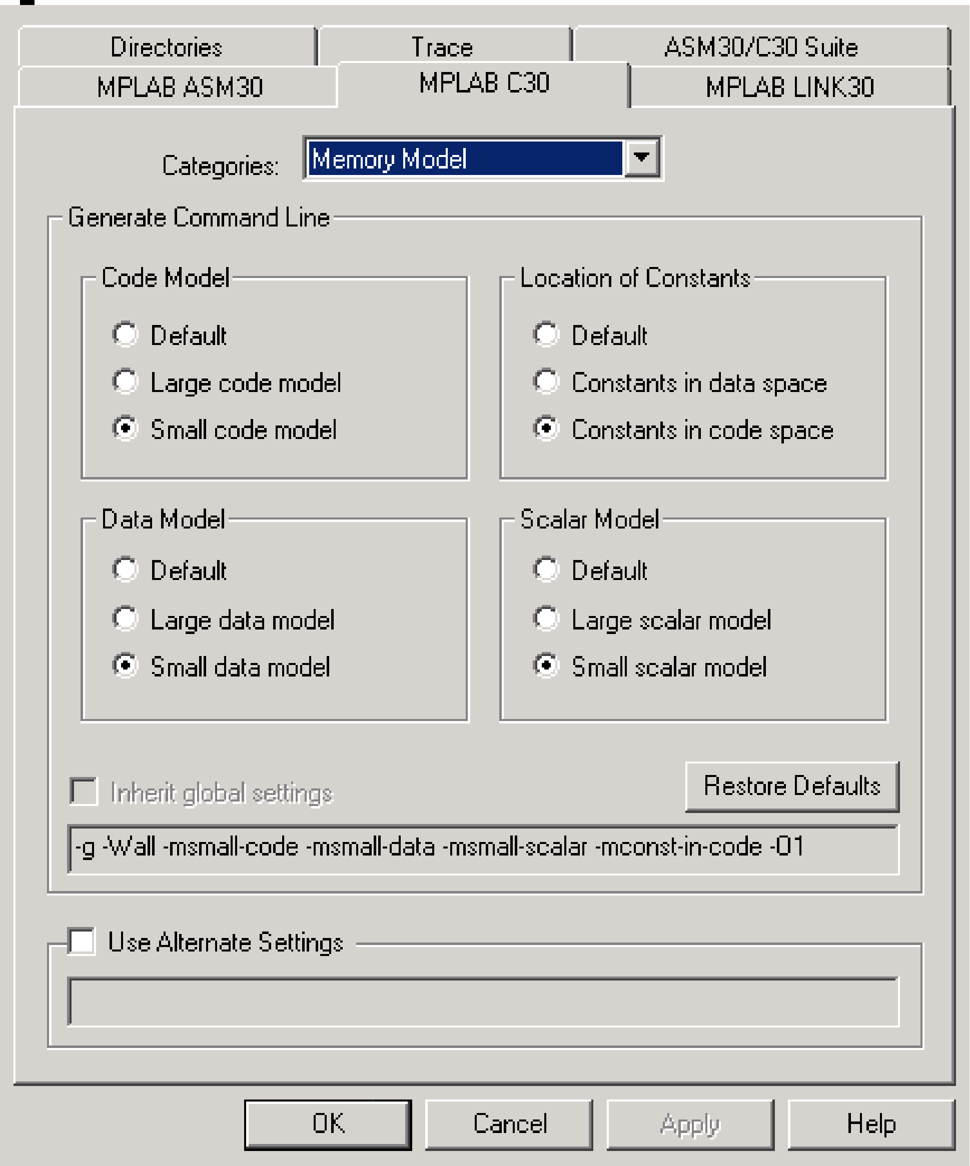
Equivalent Model Settings



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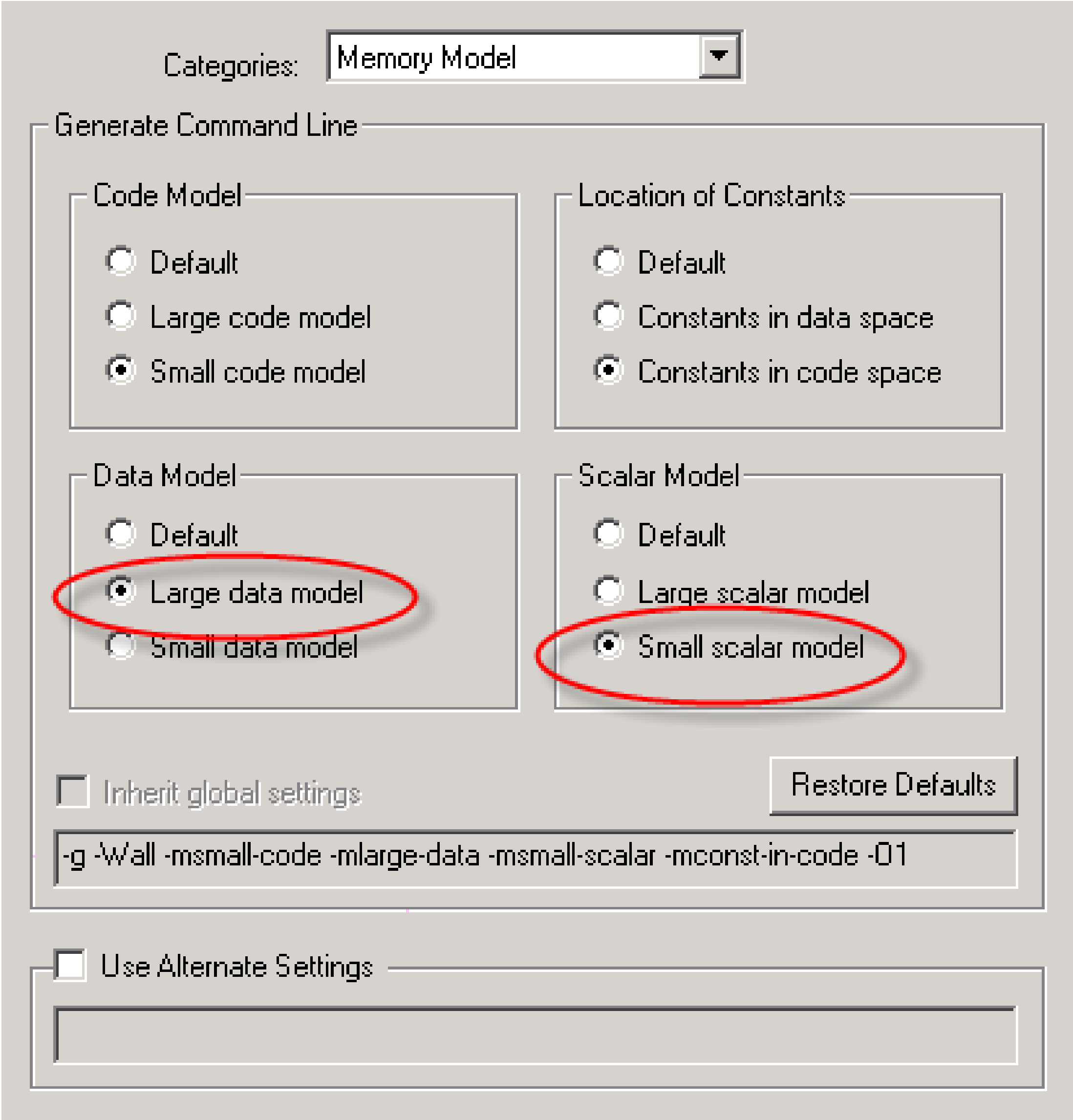
Better Model Settings?



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Individual Memory Settings

- **Global settings cannot place variables into X or Y memory!**
- **Add attributes to declarations:**

```
int my_data[256]
    __attribute__((space(xmemory)));
int more_data[1024]
    __attribute__((space(dma)));
```

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C Target Memory Attributes

- `__attribute__((space(area)));`

  where *area* is:
  - `data` - general data
  - `auto_psv` - compiler managed PSV
  - `psv` - user managed PSV
  - `xmemory` - data memory (X)
  - `ymemory` - data memory (Y)
  - `dma` - DMA memory
  - `eedata` - EEDATA memory
  - `prog` - program FLASH

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Asm Target Memory Attributes

- `.section` ***name, area***

  where *area* is:
  - **data** - initialized data memory
  - **bss** - zeroed data memory
  - **psv** - user managed PSV
  - **xmemory** - data memory (X)
  - **ymemory** - data memory (Y)
  - **dma** - DMA memory
  - **eedata** - EEDATA memory
  - **code** - program FLASH

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Individual Assembly Settings

```
 .section *,bss,xmemory
 .global _my_data
_my_data:
 .space 512

 .section *,bss,dma
 .global _more_data
_more_data:
 .space 2048
```

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Miscellaneous Attributes

- **`aligned()`** - start align boundary
- **`reverse()`** - end align boundary
- **`near`** - near data (1st 8K)
- **`far`** - far data (anywhere)
- **`address()`** - start address
- **`persistent`** - uninitialized on warm reset
- **`section`** - give a specific section name great for grouping (common PSV variables)

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Agenda

- **Mixing C & Assembly**
- **Memory Models**
- **Program Space Visibility**
  - Overview
  - Three modes of operation
- **CodeGuard™ Security Support**

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Program Space Visibility

- **PSV offers a single 32K data window into Program Flash**
- **When enabled, it is mapped into data space from 0x8000 to 0xFFFF**
- **The compiler supports 3 modes of usage for the PSV window**
  - User managed PSV support
  - Auto PSV mode
  - Compiler managed PSV

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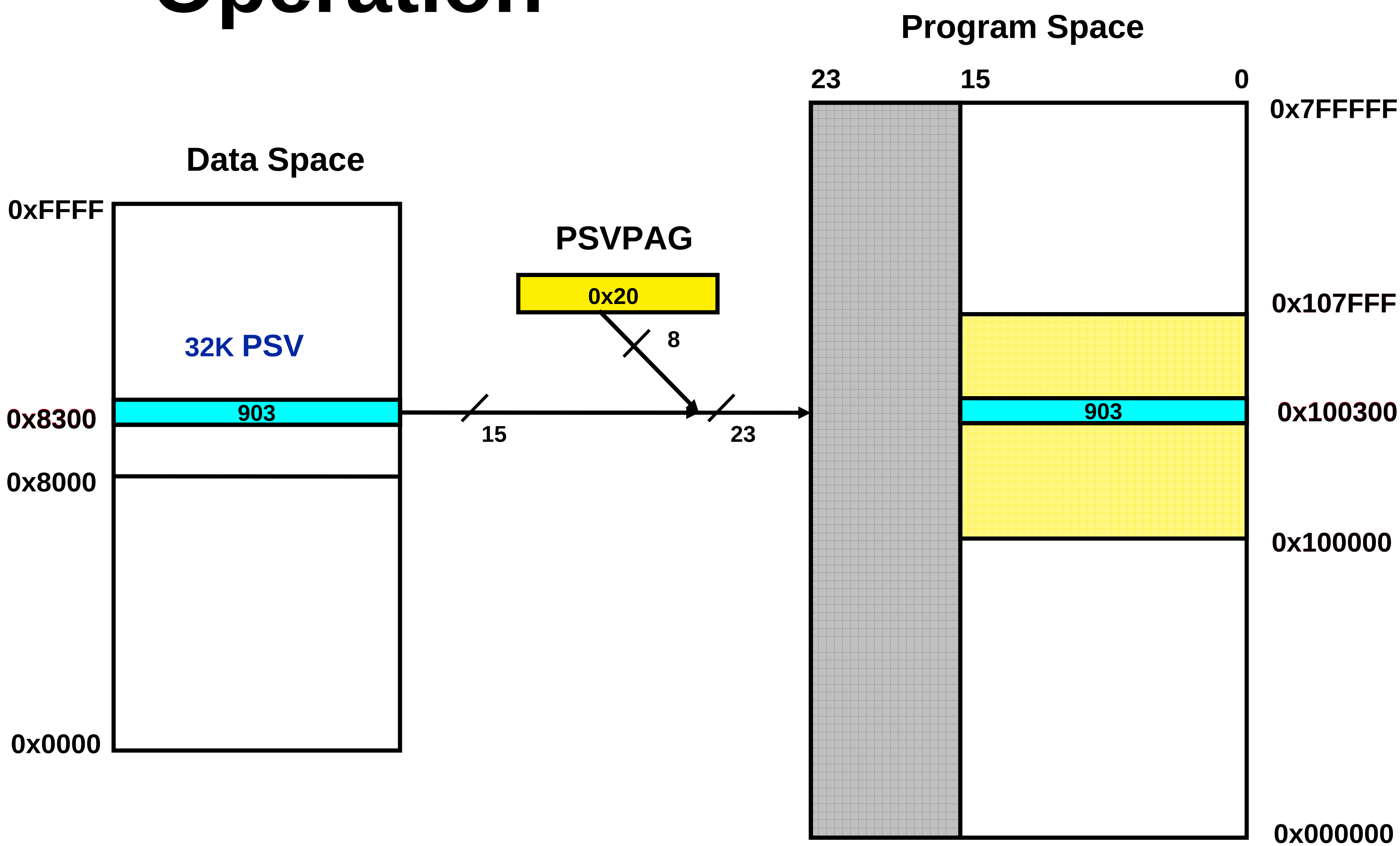
Program Space Visibility Operation



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PSV Usage

- **MPLAB® ASM30 reference: DS51317**
  - special operators, chapter 4.5
- **dsPIC30F Family Reference: DS70046**
  - hardware information
- **MPLAB C30 User's Guide: DS51284**
  - PSV info, chapter 4.15
  - Built-in function info, chapter B.2

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User Managed PSV

- **The tool chain does nothing for you!**
- **You must:**
  - Place data into Program Flash
    - `space(psv)`
  - Enable the PSV window
    - `CORCONbits.PSV = 1;`
  - Configure the PSV page
    - `PSVPAG = ???;`

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User Managed PSV Example

```
int data[256]
    __attribute__((space(psv)));

main() {
  CORCONbits.PSV = 1; // enable PSV
  PSVPAG = __builtin_psvpage(&data);
  // now safe to access data[]
  if (data[26] == 3) {
  }
}
```

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Auto PSV

- **The tool chain does (almost) everything for you!**
  - One 32K PSV page is supported
- **You must:**
  - Place data into Program Flash
    - **`space(auto_psv)`** or
    - Apply **`const`** to declarations
  - Tool chain enables PSV and sets the page

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Auto PSV Example

```
int data[256]
    __attribute__((space(auto_psv)));

main() {
  // now safe to access data[]
  if (data[26] == 3) {
  }
}
```

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Managed PSV

- **The tool chain does (almost) everything for you!**
  - Many 32K PSV pages are supported
- **You must:**
  - Place data into Program Flash
    - `space(psv)` or
    - `space(prog)`
  - Identify declaration as managed
  - Tool chain enables PSV

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Managed PSV Example

```
__psv__ int data[256]
    __attribute__((space(psv)));

main() {
  // now safe to access data[]
  if (data[26] == 3) {
  }
}
```

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Managed PSV Detail

- **Two new type qualifiers added:**

  `__psv__` - object can't cross PSV page

  `__prog__` - object may cross PSV page

- **When applied to object, the compiler will set the PSV page before access**
- **In pointer declarations, can modify the pointed to object (just like `const`)**

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Managed PSV Detail

- **Functions that take a pointer will not accept a managed PSV pointer!**
  - They are different
- **Our libraries do not currently accept managed PSV pointers**
  - `printf()` will not print a managed PSV string

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Managed PSV Examples

- **Managed PSV object**

```
__psv__ int foo
   __attribute__((space(psv)));
```

- **Pointer to object in managed PSV**

```
__psv__ int *foo_p = &foo;
```

  - pointer lives in data RAM

Managed PSV

- **Summary:**
  - Does not remove 32K data item limit
  - Pointers are larger to accommodate page information
  - Accesses are slower (page must be set)
  - Interrupt service routines may need modification
  - Beta support

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Agenda

- **Mixing C & Assembly**
- **Memory Models**
- **Program Space Visibility**
- **CodeGuard™ Security Support**
  - Boot, Secure Segments
  - Execution Control
  - Security Model

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CodeGuard™ Security

- **What is CodeGuard Security?**
  - **A hardware feature that…**
    - Partitions memory into 2 or 3 segments
    - Controls visibility and execution between segments
- **How is it useful?**
  - **Allows multiple parties to share resources on a single chip**

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CodeGuard™ Security

- **What device families have CodeGuard Security?**
  - **dsPIC33F, PIC24H, and several dsPIC30F devices**
  - **But the language extensions are useful on any device!**

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CodeGuard™ Security

- **Documentation available at www.microchip.com/codeguard:**
  - Reference Manual
  - White Paper
  - Web Seminar

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Boot & Secure Segments

- **Memory can be partitioned**
  - into 1 or 2 special segments
  - plus the general segment
- **Segment sizes can be small, medium, or large (varies by device)**
- **Each segment can be linked separately**

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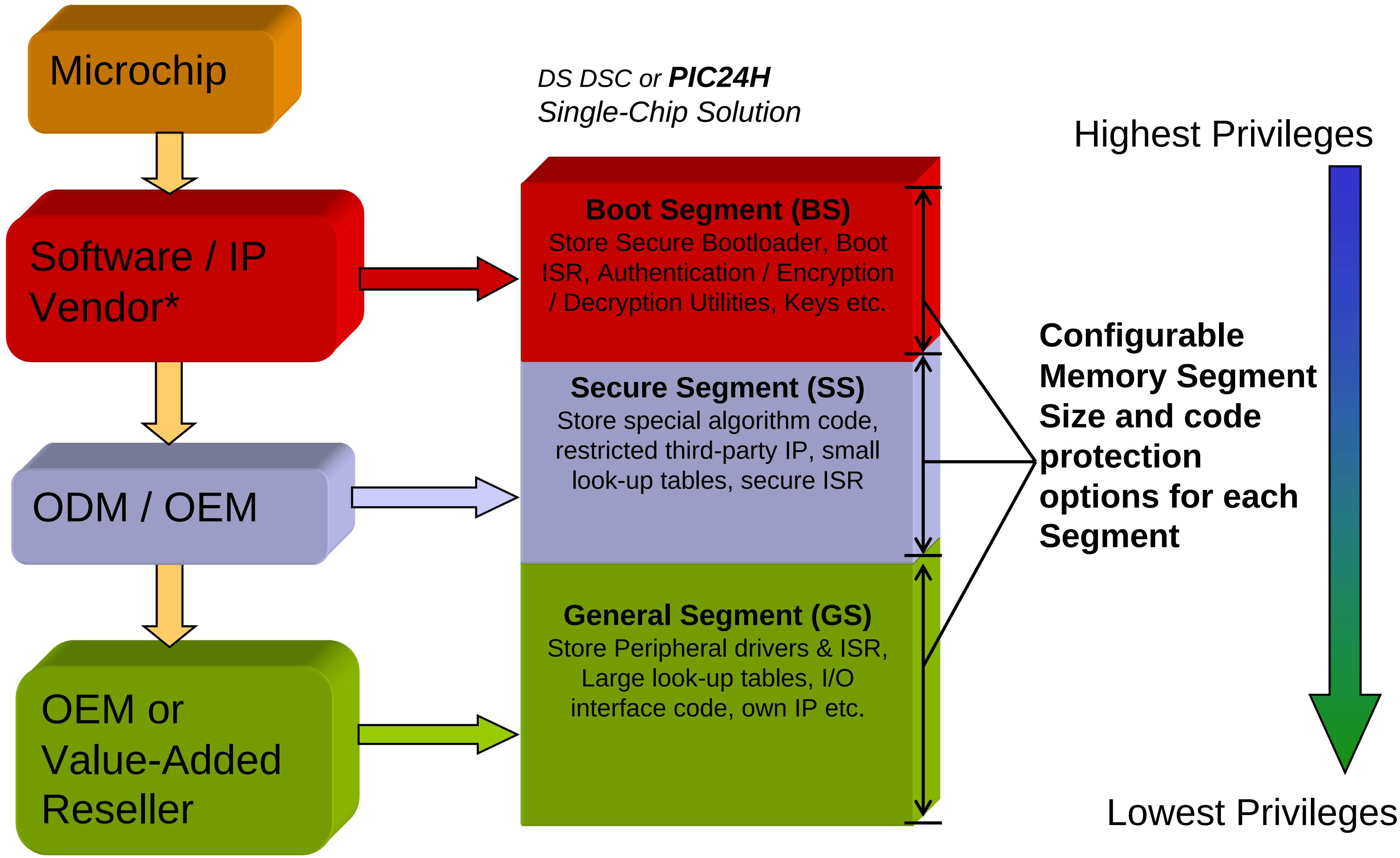
Boot & Secure Segments



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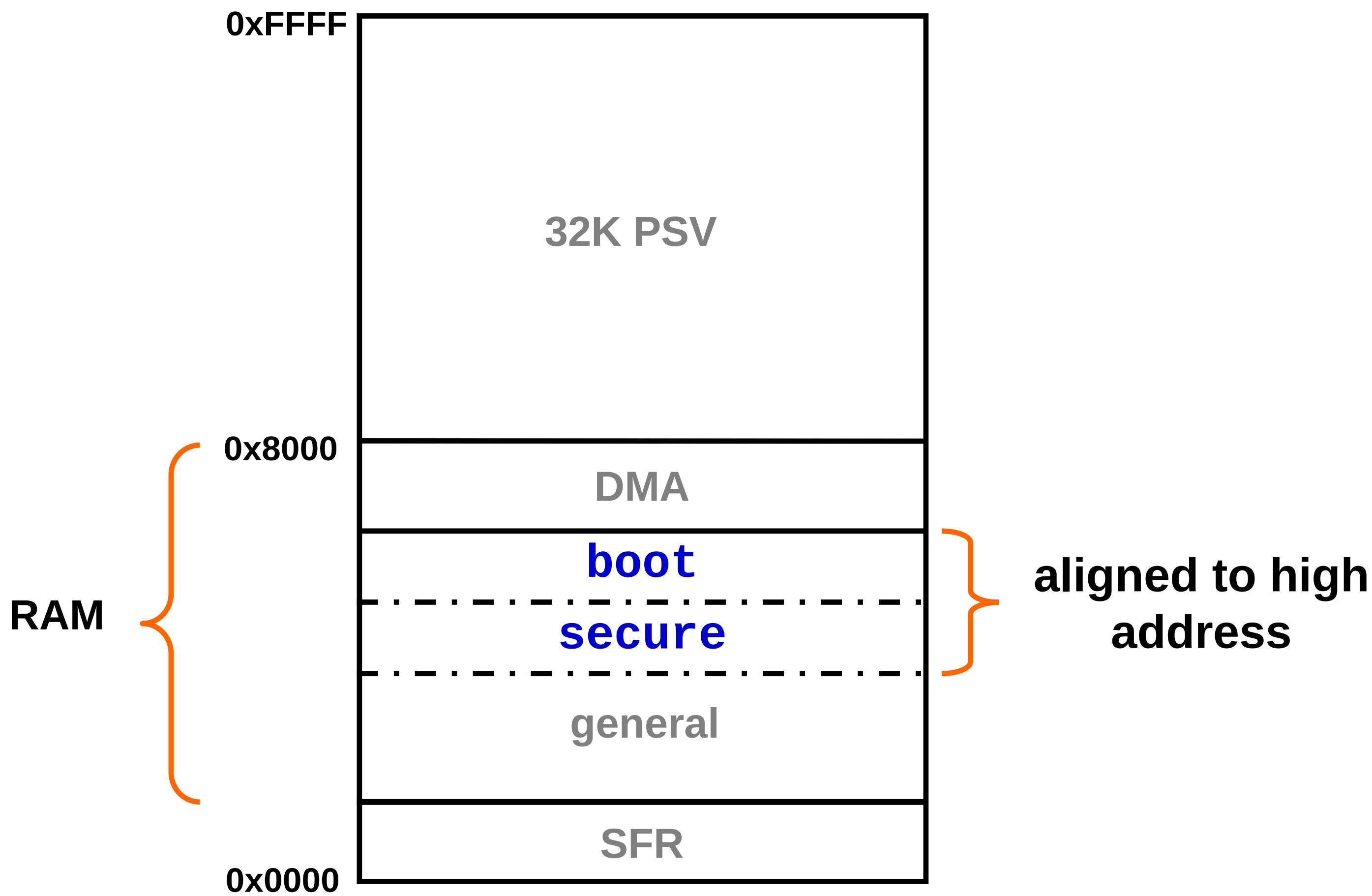
Segments in Data Space



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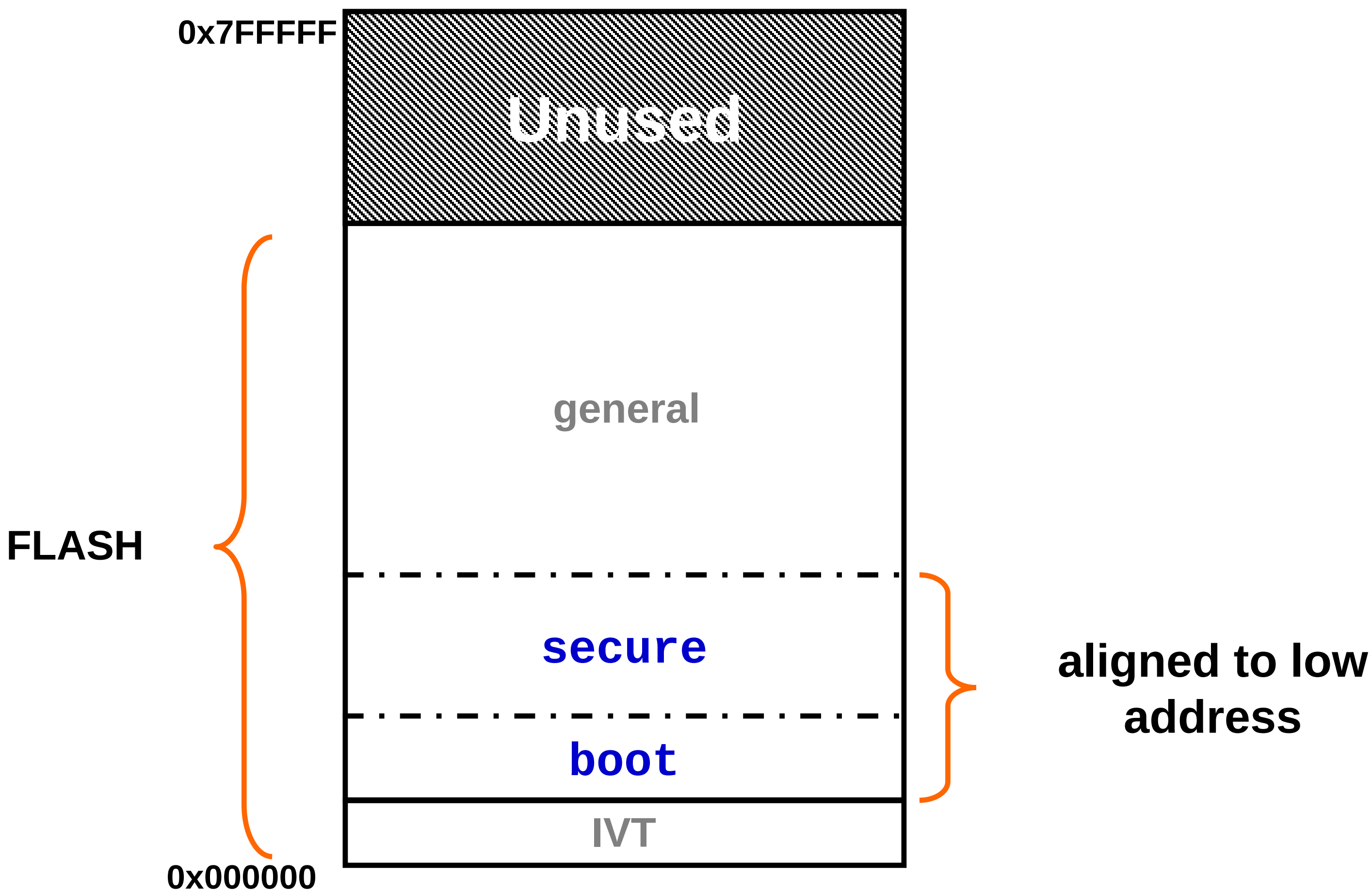
Segments in Program Space



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Execution Control

- **Higher privilege segments can always call lower segments**
- **Standard Security**
  - Calls to higher segment are permitted
- **High Security**
  - Calls to higher segment must be vectored through access area

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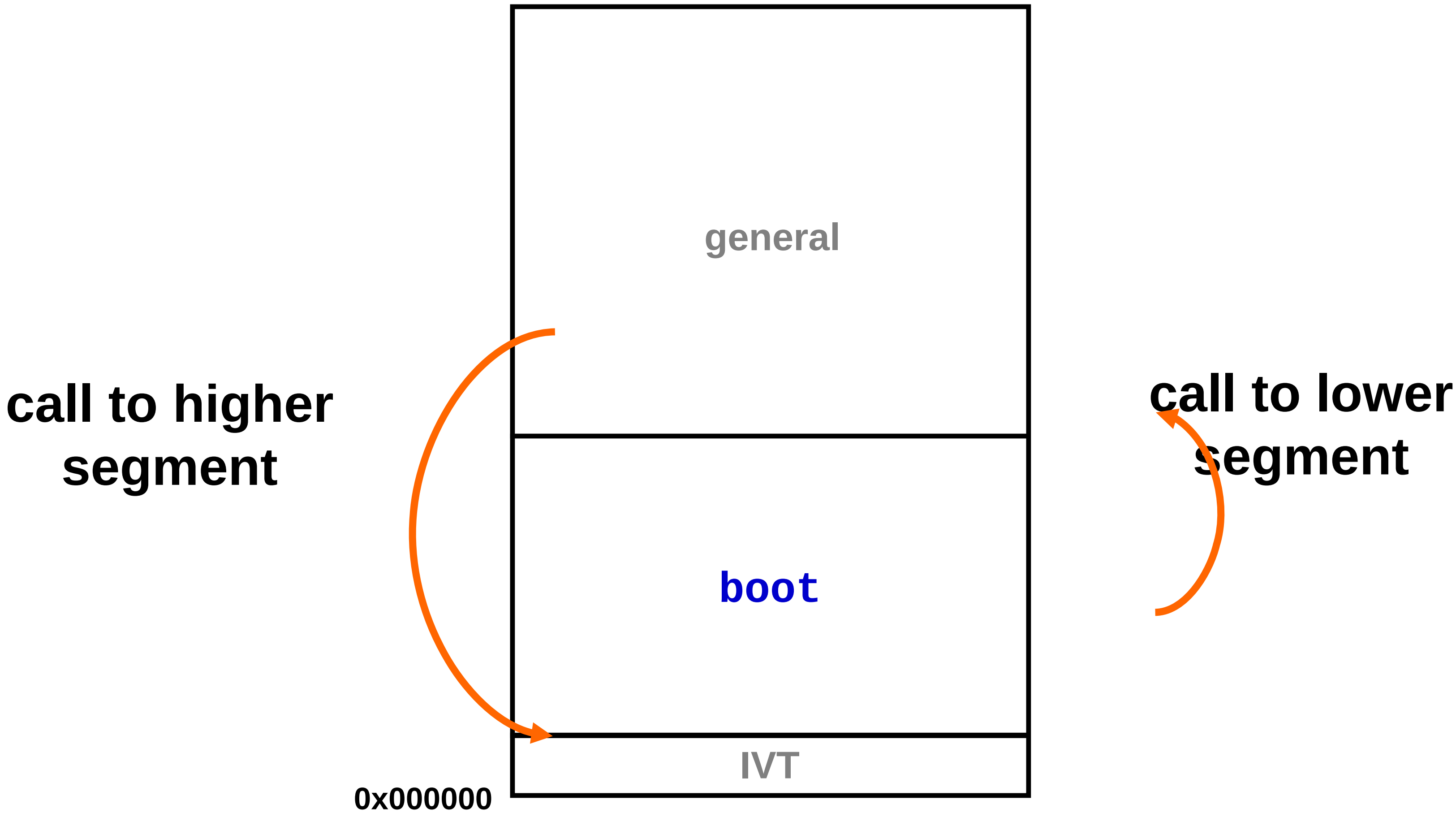
Execution Control: Standard Security



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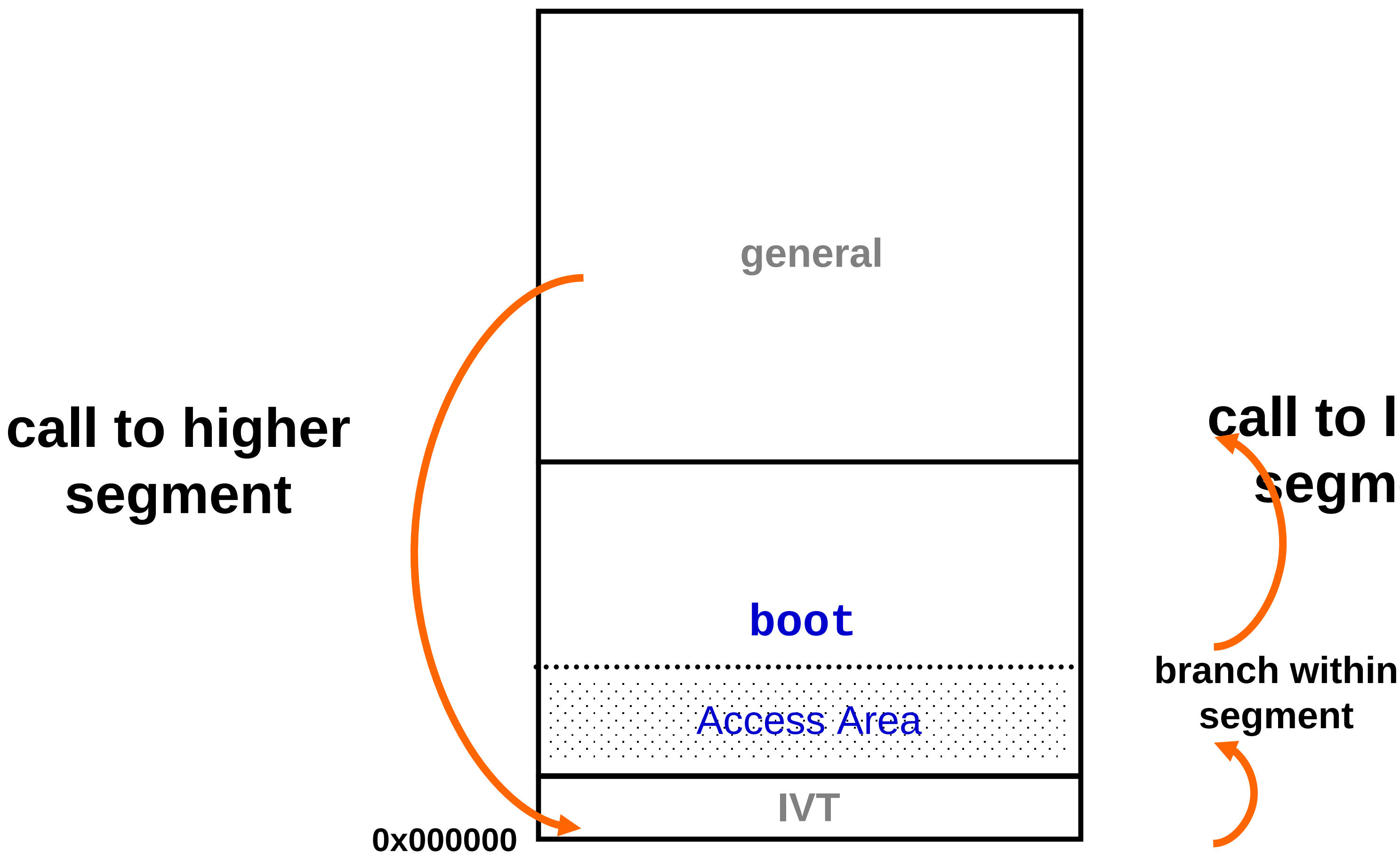
Execution Control: High Security



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Access Area

- **With high security:**
  - only the first 32 locations are accessible to a lower privilege segment
  - tools create access area and manage references automatically
  - implemented as a branch table

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Access Area

- **Transfer of control by slot number is the key to separately linked program segments**
- **Use these constructs on any device**
  - even without CodeGuard™ Security in hardware

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Access Area Example: C

- How can I call an access slot?
- First, declare the function

```
extern void __attribute__((boot(4)))
  myfunction(void);
```

- Then call it as a normal function!

```
void main(void) {
   myfunction();
   /* and so on */
}
```

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C Example, cont.

- How can I define an access slot?
- Use the boot or secure attribute

```
void __attribute__((boot(4)))
  entry4(void)
 {
   /* insert code here */
 }
```

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Access Area Example: Asm

- How can I call an access slot?
- Use the boot or secure operator

```
call  boot(4)
rcall secure(2)
bra   cc,boot(8)

mov   #boot(5),w0 ; 16-bit address
call  w0
```

Asm Example, cont.

- How can I define an access slot?
- Use the boot or secure attribute

```
    .section *,code,boot(4)
    .global _entry4
_entry4:
    ; do something
    return
```

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Boot & Secure Interrupts

- While executing in a boot or secure segment, all interrupts vectored through access area
- All interrupt sources use a single access entry slot (16)

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Interrupt Example: C

- How can I define a boot interrupt handler?

```
void __attribute__((interrupt,boot))
  my_boot_isr(void) {
  /* insert code here */
}
```

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Interrupt Example: Asm

- **How can I define a boot interrupt handler?**

```
.section *,code,boot(isr)
    .global _my_boot_isr
_my_boot_isr:
    ; do something
    retfie
```

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Security Model

- **Segment sizes and options are encoded into 3 config words:**
  - FBS: boot segment
  - FSS: secure segment
  - FGS: general segment

- **Together, these settings comprise the 'Security Model'**

Security Model Example: C

- **Define in source code**

```
#include <p33Fxxxx.h>

_FBS(BSS_SMALL_FLASH_HIGH &
  BRWP_WRPROTECT_ON);
_FSS(SSS_MEDIUM_FLASH_STD);
_FGS(GWRP_OFF);
```

- **Or use the IDE**
  - Build Options:LINK30:Code Guard

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Security Model Example: ASM

- **Define in source code**

```
.include "p33Fxxxx.inc"

config _FBS, BSS_SMALL_FLASH_HIGH &
    BRWP_WRPROTECT_ON
config _FSS, SSS_MEDIUM_FLASH_STD
config _FGS, GWRP_OFF
```

- **Or use the IDE**
  – Build Options:LINK30:Code Guard

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User-Defined Security Model

- For devices without CodeGuard™ Security in hardware
- Use linker command options

```
--boot flash_size=128
--boot ram_size=64

--secure flash_size=256
--secure ram_size=64:flash_size=256
```

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Class Summary

- **Mixing C and Assembly**
- **Memory Models**
- **Program Space Visibility**
- **CodeGuard™ Security**

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Additional Resources

- Microchip Web Site
  - Student Edition version of tool suite
  - C30 README file
  - 16-Bit reference material
  - Development boards
  - Silicon

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Q & A

- **Questions?**
- **More questions?**
  – Go to “Ask the Experts”
  – Visit the online forum!

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