the Brainware company

THE DSPACE SDE

DSPACE

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SEVENTH FRAMEWORK PROGRAMME

The research leading to these results has received funding from
the European Community's Seventh Framework Programme ([FP7/2007-2013]) under Grant Agreement n°262798

OUTLINE

- ✓ Requirements
- ✓ SDE modules and architecture
- ✓ Usage and Examples
- ✓ Conclusions

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DSPACE SDE

MAIN REQUIREMENTS

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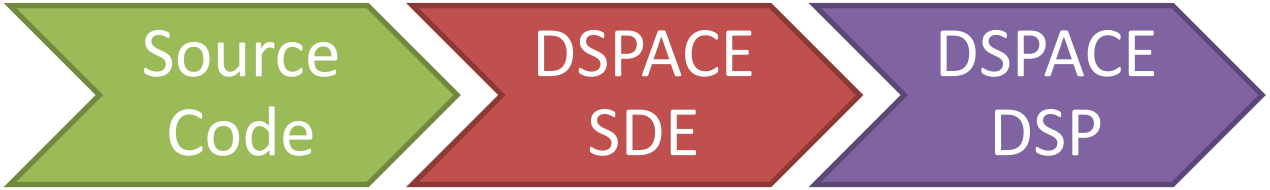
WHY A DSPACE SDE?

- The DSPACE is a new VLIW Digital Signal Processor
  - New hardware architecture
  - New instructions Set
- Existing software products cannot be used to operate on this device
- A new set of dedicated tools must be provided as a necessary supplement to the hardware
  - Compiler
  - Assembler
  - Linker
  - Debugger
  - Simulator
  - Device drivers
- The DSPACE SDE (Software Development Environment) is the collection of software components that programmers can use to develop DSPACE software



Source Code

DSPACE SDE

DSPACE DSP

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MAIN REQUIREMENTS

- To provide a consistent **Software Development Environment** (SDE) for the DSPACE is a task of critical importance
- A comprehensive, easy to use, reliable software environment with standard functionality is required
  - Programmers want to be able to write code for the new processor the way they are accustomed to, using well-known interfaces
- The use of existing software, where applicable, is strongly encouraged

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AVAILABLE TOOLS

- The DSPACE processor architecture has been described using the LISA language
- From the LISA description, the following tools were automatically generated
  - Assembler
  - Linker
  - Other tools (e.g., debugger, simulator)

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DSPACE SDE

MODULES AND ARCHITECTURE

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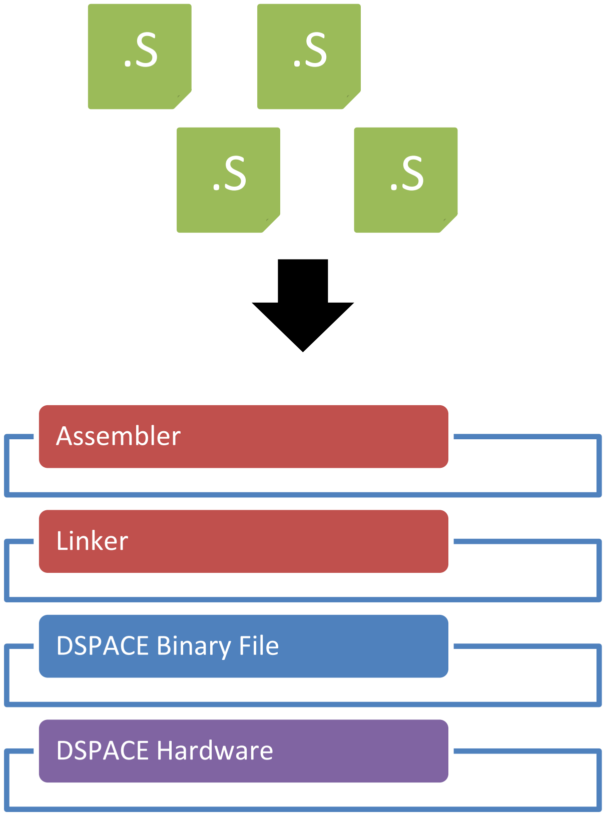
A POSSIBLE WORKFLOW

- With the Assembler and the Linker a first development workflow is made possible
  - Source code is written in the DSPACE **assembly** language
  - Object code is generated by the **Assembler**
  - The **Linker** creates the final executable



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BEYOND ASSEMBLY SUPPORT

- To manually write assembly code is generally a poor solution for developers
  - Error prone
  - Hard to maintain
  - Time-consuming
  - Difficult to implement (VLIW architecture)
    - ❑ Resource allocation
    - ❑ Code scheduling
    - ❑ Register spilling
    - ❑ Parallel instructions
- Common practice to optimize small critical code portions
- This is not enough to ensure the success of the new hardware
- Developers must be provided with a C source code compiler

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BUILDING A DSPACE C COMPILER

- New module to let programmers develop in C
- Requirements for a DSPACE C Compiler module
  - Assembler and linker already available
  - **Compile C source code into DSPACE Assembly**
  - This completes the tool-chain
- Implementation strategies
  - Create a new dedicated compiler from scratch
  - Build on top of existing software components (e.g. reuse C front-end capabilities)
- Survey of existing software tool-chains led to **gcc**-based implementation
  - Usability
  - Maturity
  - Reliability
  - Quality
  - Licensing
  - Source code availability

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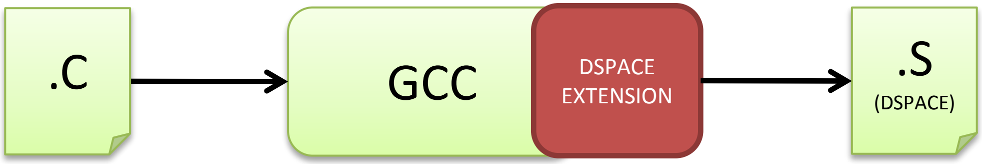
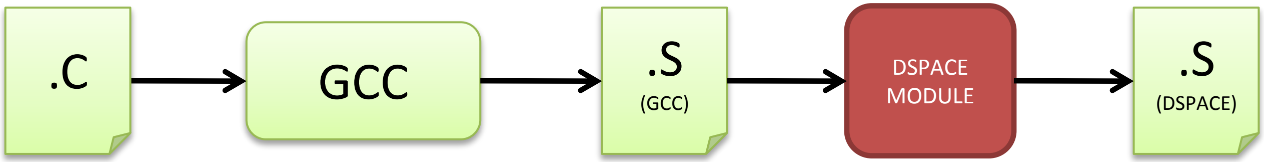
GCC INTEGRATION SCHEMES

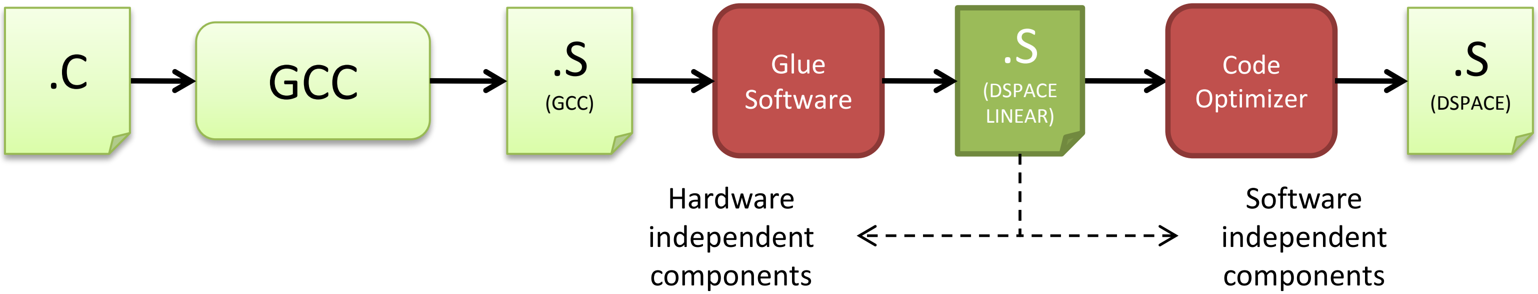
- Different integration schemes were envisaged in order to build the **DSPACE compiler** from the **GCC**
  - Extend the GCC compiler back-end by accessing its source code



  - Single component adapting GCC output to DSPACE



  - Two components creating an abstraction layer between software and hardware



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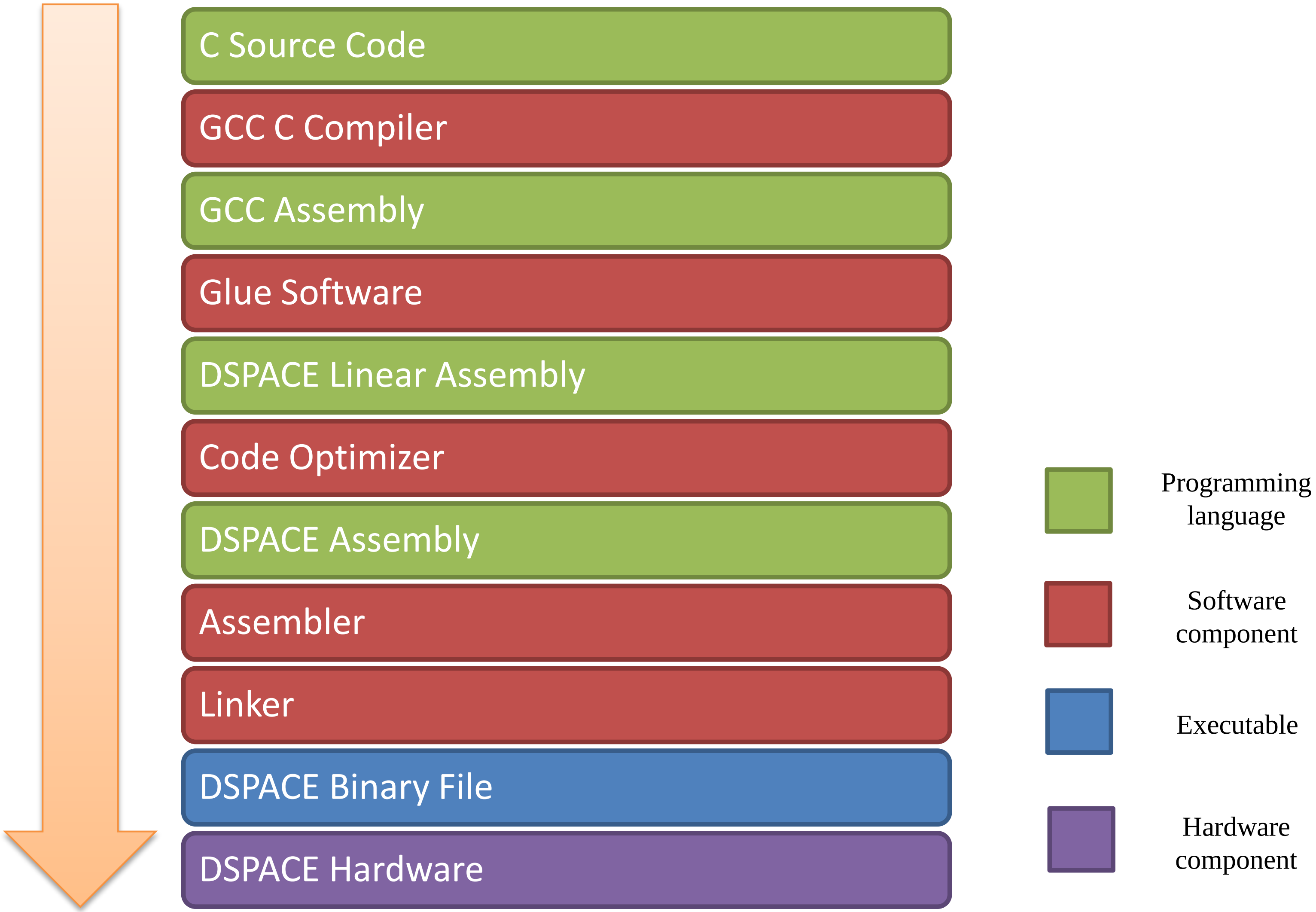
COMPLETE DSPACE TOOL-CHAIN



C Source Code

GCC C Compiler

GCC Assembly

Glue Software

DSPACE Linear Assembly

Code Optimizer

DSPACE Assembly

Assembler

Linker

DSPACE Binary File

DSPACE Hardware

🟩 Programming language

🟥 Software component

🟦 Executable

🟪 Hardware component

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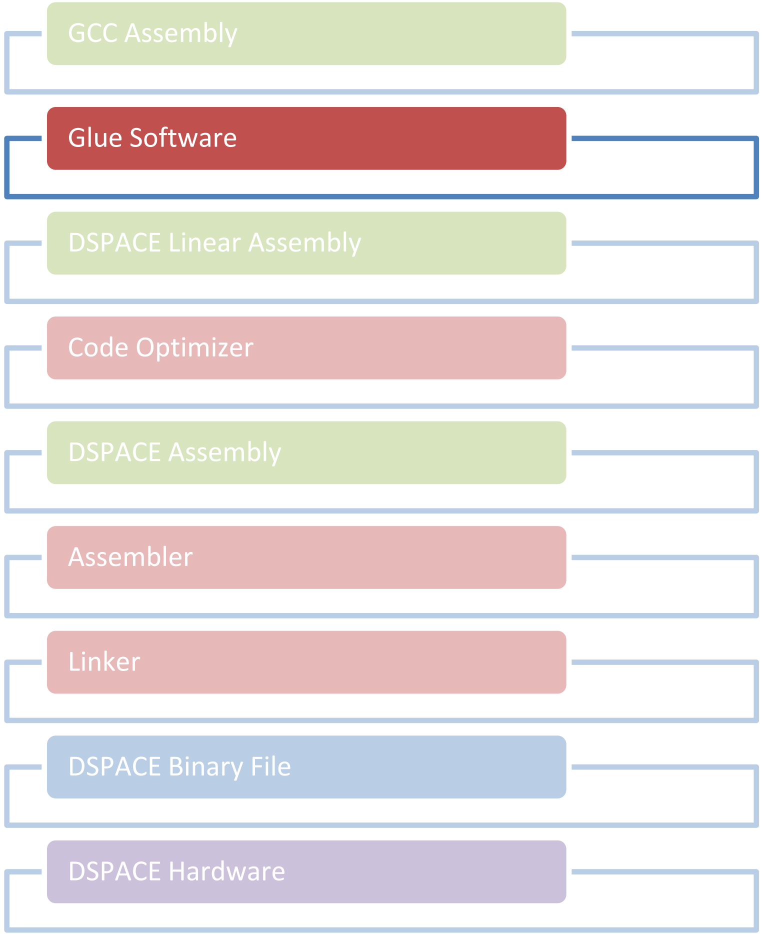
THE GLUE SOFTWARE

- INPUT
  - Assembly code generated by the **GCC**
- OPERATIONS
  - Source code parsing
  - Code transformations for hardware abstraction (e.g., SSA)
    - ❑ Enables for more code optimizations
    - ❑ Removes hardware constraints
    - ❑ (Hardware independent optimizations are kept from the GCC)
  - Instruction set translation
- OUTPUT
  - DSPACE **Linear** Assembly



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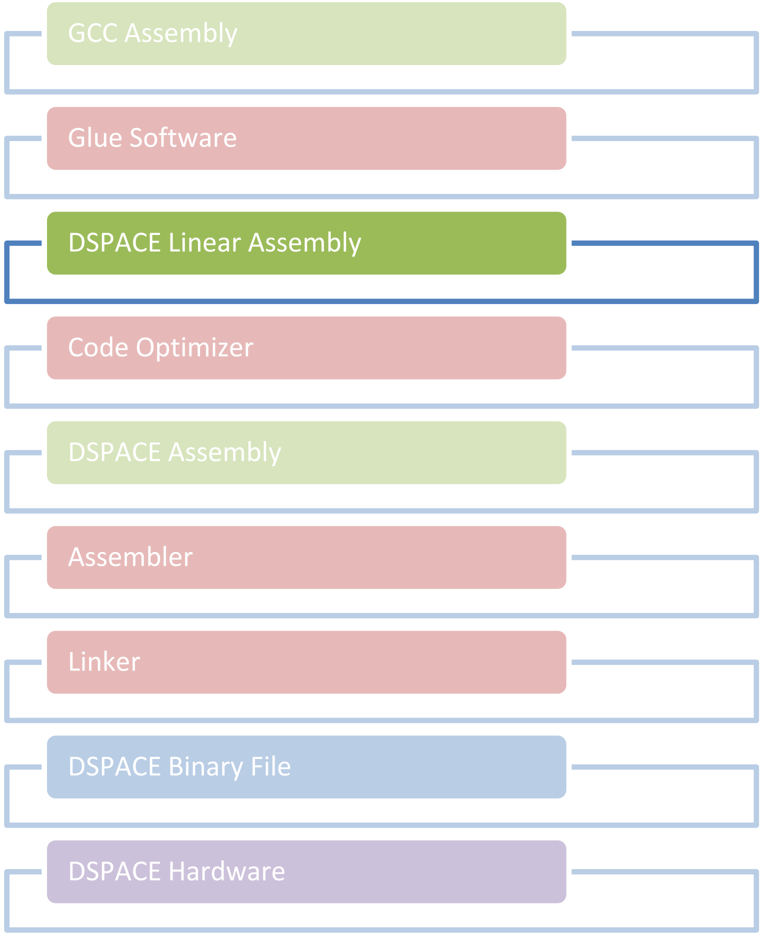
DSPACE LINEAR ASSEMBLY

- Language specification
- Hardware independent form of DSPACE Assembly (w/DSPACE instruction set)
  - No functional units specification
  - No code scheduling
    - ❑ Order of statements corresponds to order of execution (no delay slots)
  - Virtual registers (infinite number of registers)
  - No parallel statements
- Abstract interface between Glue Software and Code Optimizer
  - Decouples hardware from software (and vice-versa)
  - Makes the development of the tool-chain easier
- Can be easily developed manually



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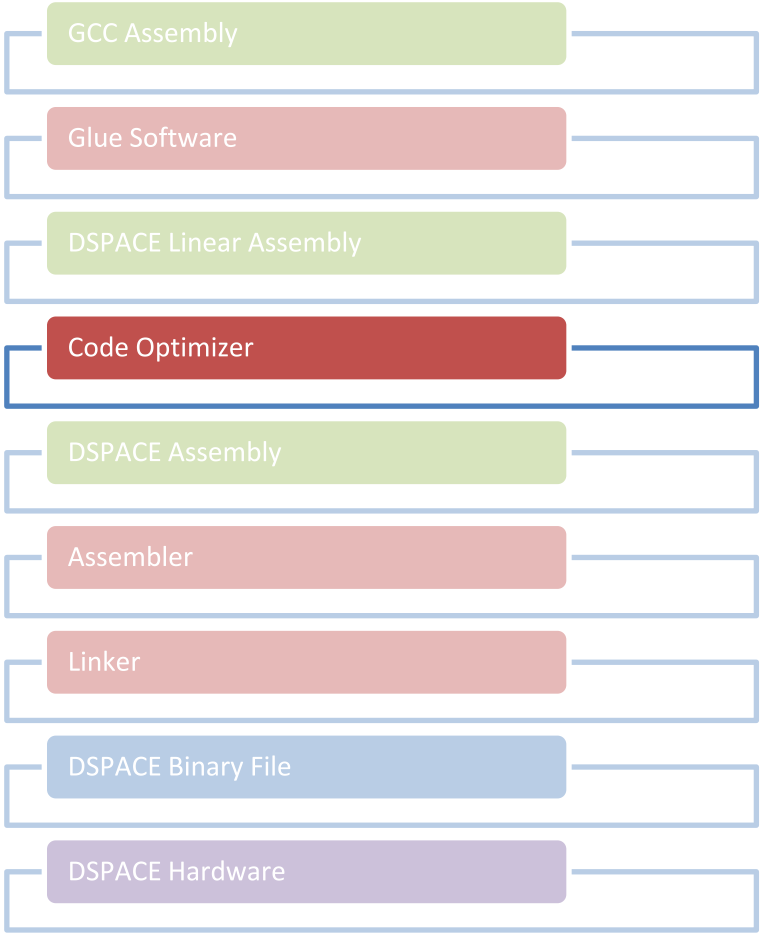
CODE OPTIMIZER

- INPUT
  - DSPACE Linear Assembly
- OPERATIONS
  - Code scheduling
  - Registers allocation
  - Functional units assignment
  - Introduction of VLIW parallelism
  - Code Optimizations
- OUTPUT
  - DSPACE Assembly



GCC Assembly

Glue Software

DSPACE Linear Assembly

Code Optimizer

DSPACE Assembly

Assembler

Linker

DSPACE Binary File

DSPACE Hardware

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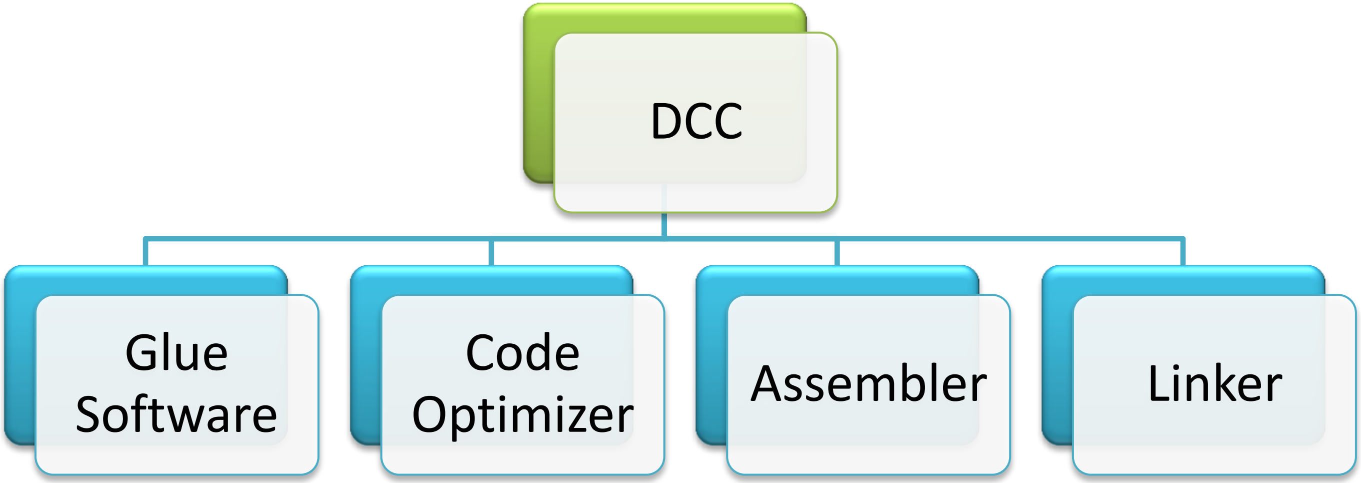
DCC (DSPACE C COMPILER) AS A WHOLE

- The DCC is the single DSPACE software component that calls the modules of the tool-chain
- It globally operates as a static binary translation compiler
- It has the same Command Line Interface as the **gcc** (plus DSPACE specific options)



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USAGE AND EXAMPLES

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DCC CLI USAGE

- Usage:

```
        dcc [options] file...
```

- Options:
  - Same as GCC, plus DSPACE specific

- Example:

```
        dcc -O2 -Wall main.c --keep-temps -I../include/
```

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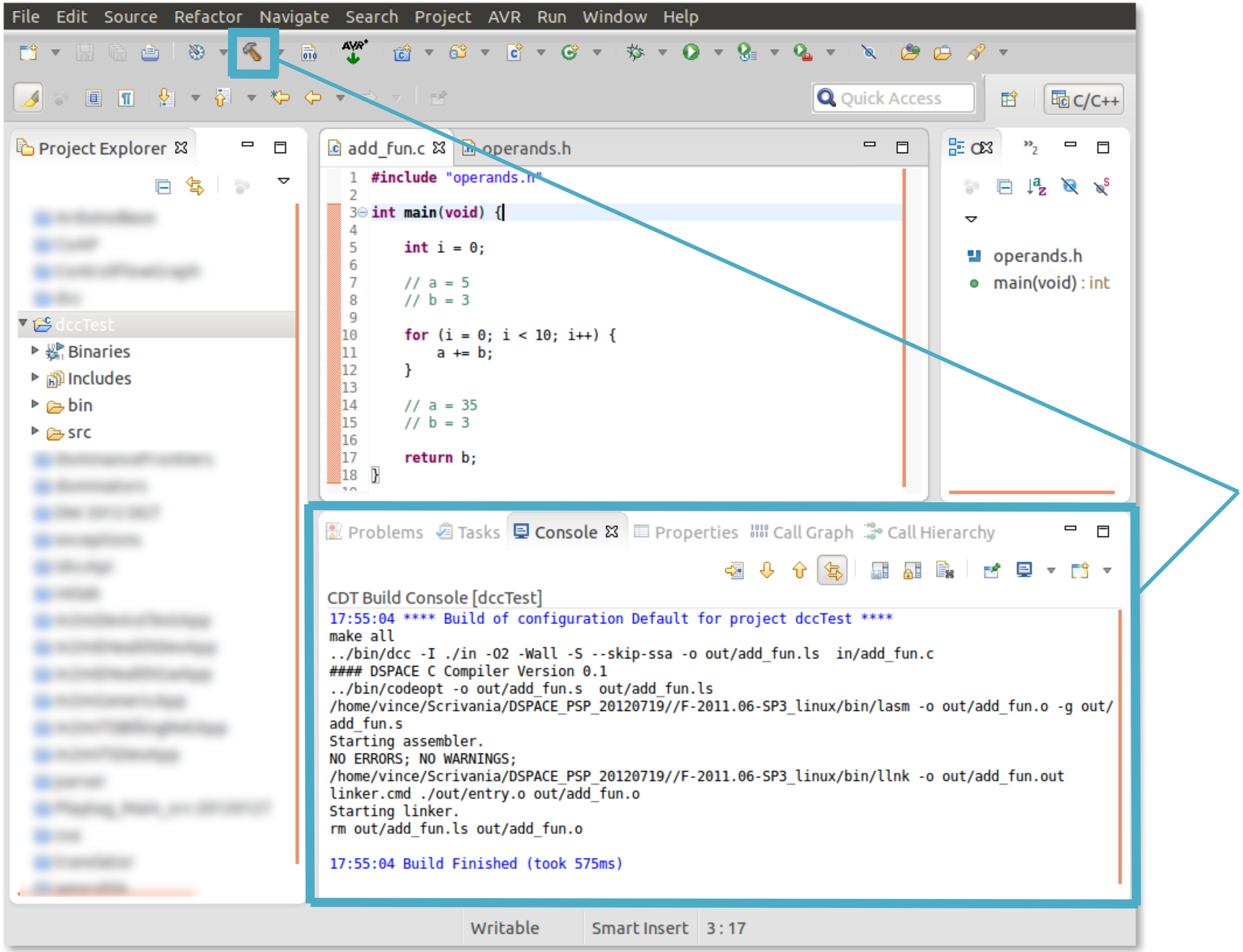
ECLIPSE INTEGRATION - BUILD



```
#include "operands.h"

int main(void) {

    int i = 0;

    // a = 5
    // b = 3

    for (i = 0; i < 10; i++) {
        a += b;
    }

    // a = 35
    // b = 3

    return b;
}
```

CDT Build Console [dccTest]

```
17:55:04 **** Build of configuration Default for project dccTest ****
make all
../bin/dcc -I ./in -O2 -Wall -S --skip-ssa -o out/add_fun.ls  in/add_fun.c
#### DSPACE C Compiler Version 0.1
../bin/codeopt -o out/add_fun.s  out/add_fun.ls
/home/vince/Scrivania/DSPACE_PSP_20120719//F-2011.06-SP3_linux/bin/lasm -o out/add_fun.o -g out/
add_fun.s
Starting assembler.
NO ERRORS; NO WARNINGS;
/home/vince/Scrivania/DSPACE_PSP_20120719//F-2011.06-SP3_linux/bin/llnk -o out/add_fun.out
linker.cmd ./out/entry.o out/add_fun.o
Starting linker.
rm out/add_fun.ls out/add_fun.o

17:55:04 Build Finished (took 575ms)
```

DSPACE
Tool-Chain
Eclipse
Integration

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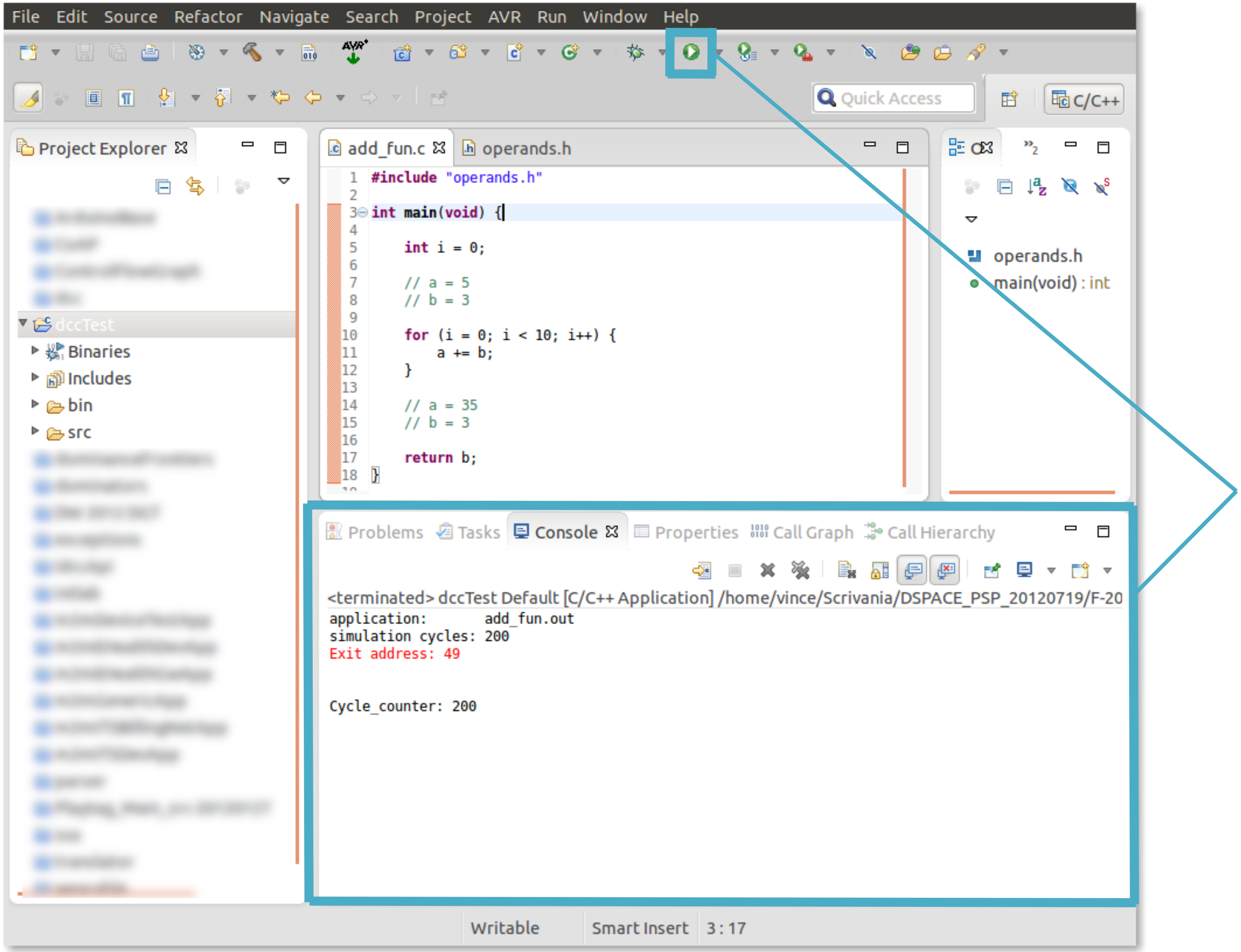
ECLIPSE INTEGRATION - RUN



```
#include "operands.h"

int main(void) {

    int i = 0;

    // a = 5
    // b = 3

    for (i = 0; i < 10; i++) {
        a += b;
    }

    // a = 35
    // b = 3

    return b;
}
```

```
<terminated> dccTest Default [C/C++ Application] /home/vince/Scrivania/DSPACE_PSP_20120719/F-20
application:       add_fun.out
simulation cycles: 200
Exit address: 49


Cycle_counter: 200
```

DSPACE
Simulator
Eclipse
Integration

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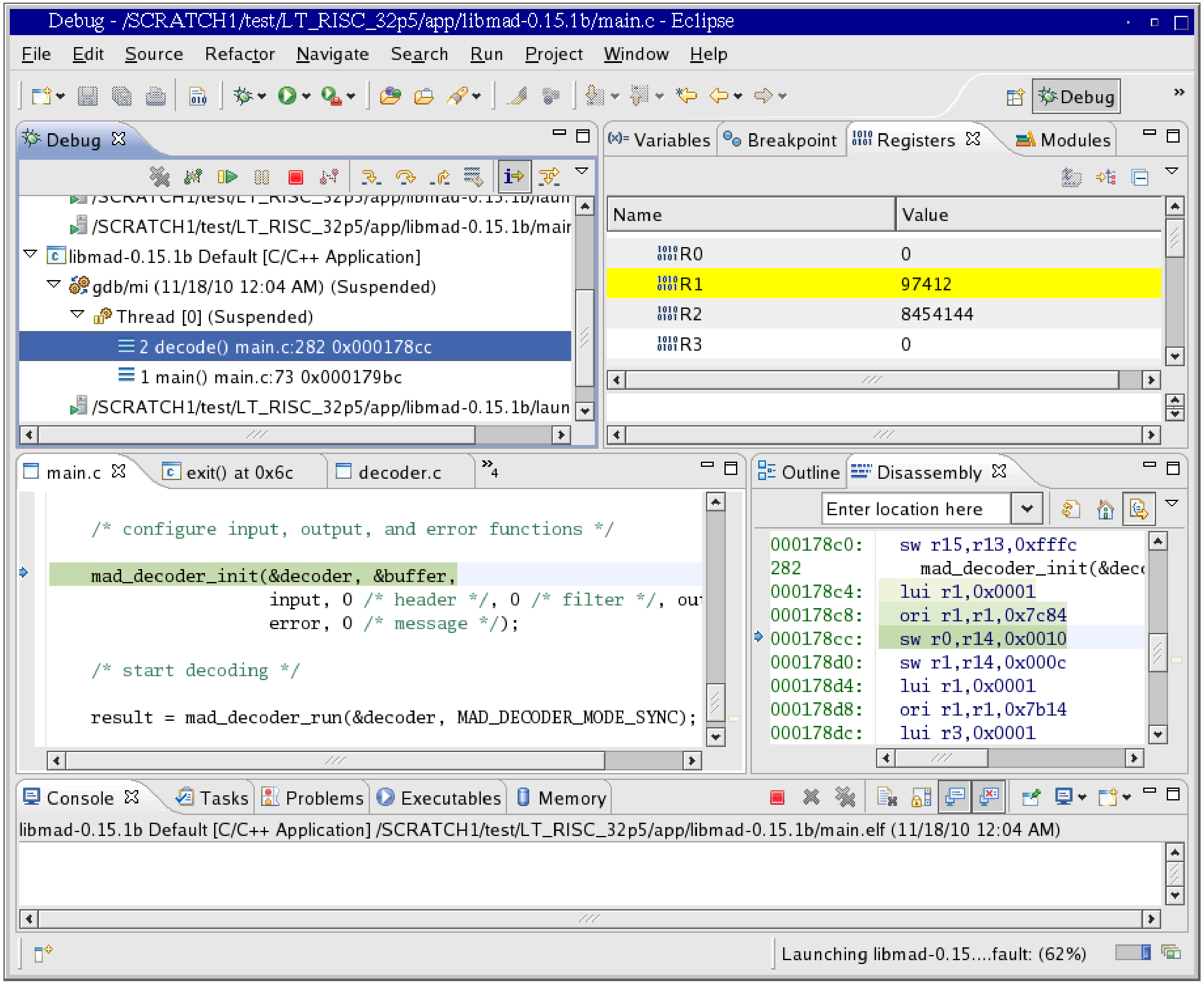
ECLIPSE INTEGRATION - DEBUGGER



Debug - /SCRATCH1/test/LT_RISC_32p5/app/libmad-0.15.1b/main.c - Eclipse

```
/SCRATCH1/test/LT_RISC_32p5/app/libmad-0.15.1b/laun
/SCRATCH1/test/LT_RISC_32p5/app/libmad-0.15.1b/mair
libmad-0.15.1b Default [C/C++ Application]
  gdb/mi (11/18/10 12:04 AM) (Suspended)
    Thread [0] (Suspended)
      2 decode() main.c:282 0x000178cc
      1 main() main.c:73 0x000179bc
/SCRATCH1/test/LT_RISC_32p5/app/libmad-0.15.1b/laun
```

Name	Value
R0	0
R1	97412
R2	8454144
R3	0

```
  /* configure input, output, and error functions */

  mad_decoder_init(&decoder, &buffer,
                   input, 0 /* header */, 0 /* filter */, ou
                   error, 0 /* message */);

  /* start decoding */

  result = mad_decoder_run(&decoder, MAD_DECODER_MODE_SYNC);
```

```
000178c0:   sw r15,r13,0xfffc
282           mad_decoder_init(&dec
000178c4:   lui r1,0x0001
000178c8:   ori r1,r1,0x7c84
000178cc:   sw r0,r14,0x0010
000178d0:   sw r1,r14,0x000c
000178d4:   lui r1,0x0001
000178d8:   ori r1,r1,0x7b14
000178dc:   lui r3,0x0001
```

```
libmad-0.15.1b Default [C/C++ Application] /SCRATCH1/test/LT_RISC_32p5/app/libmad-0.15.1b/main.elf (11/18/10 12:04 AM)
```

Launching libmad-0.15....fault: (62%)

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CONCLUSIONS

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CONCLUSIONS

- A new DSP processor has been designed within the DSPACE FP7 project
- For the success of the processor among software developers a complete tool-chain was strongly required
- We have developed the components for a DSPACE dedicated tool-chain that include hardware specific optimizations
- The DCC (DSPACE C Compiler) can be used from the command line with a well-known and standard interface or integrated into famous IDEs such as Eclipse

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THANK YOU!

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