The **HercuLeS** HLS environment

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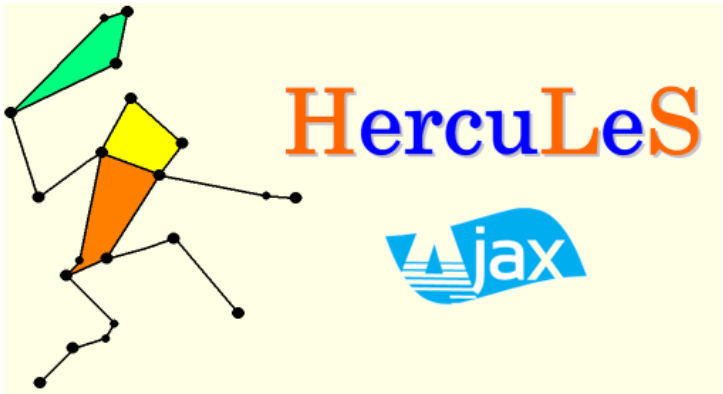
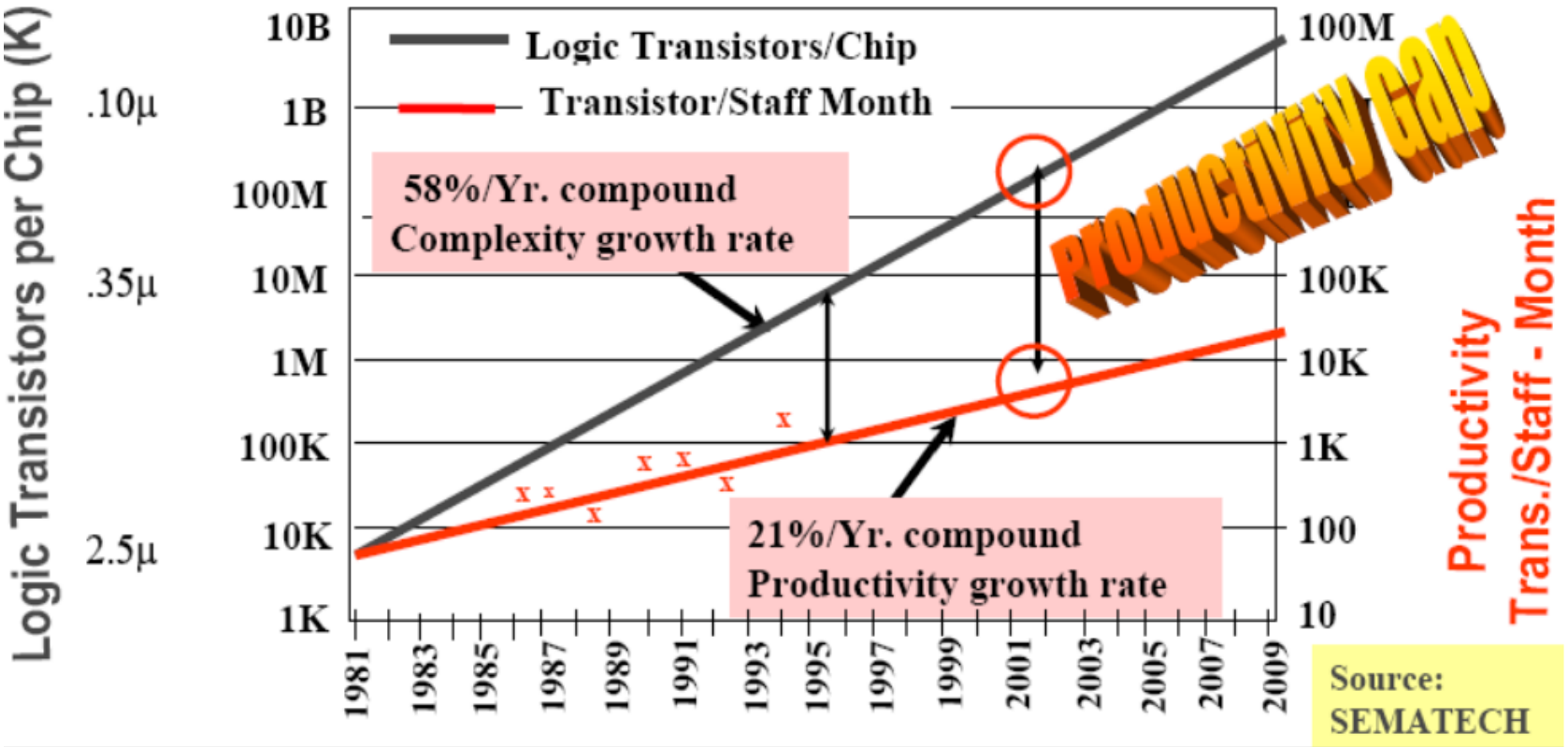
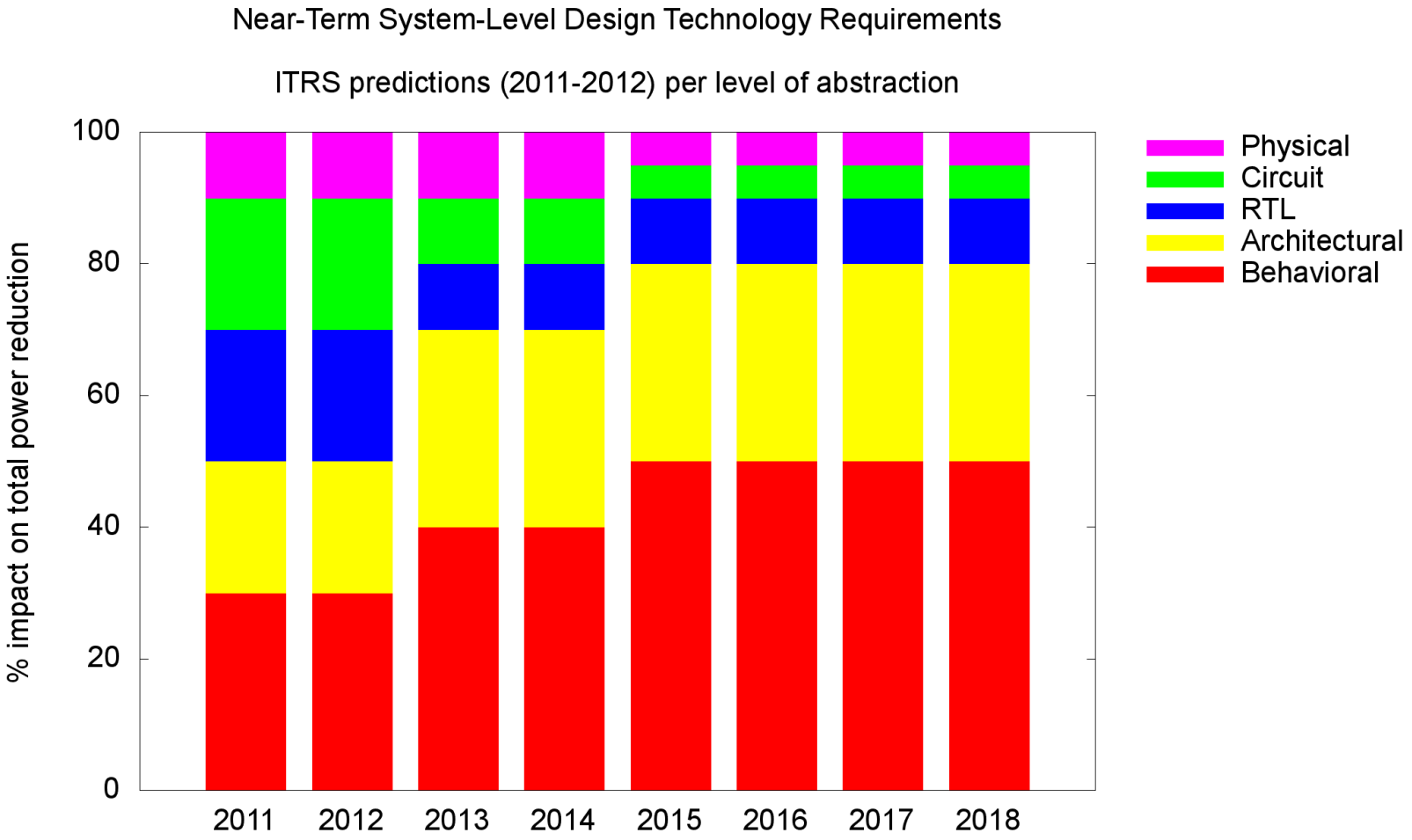


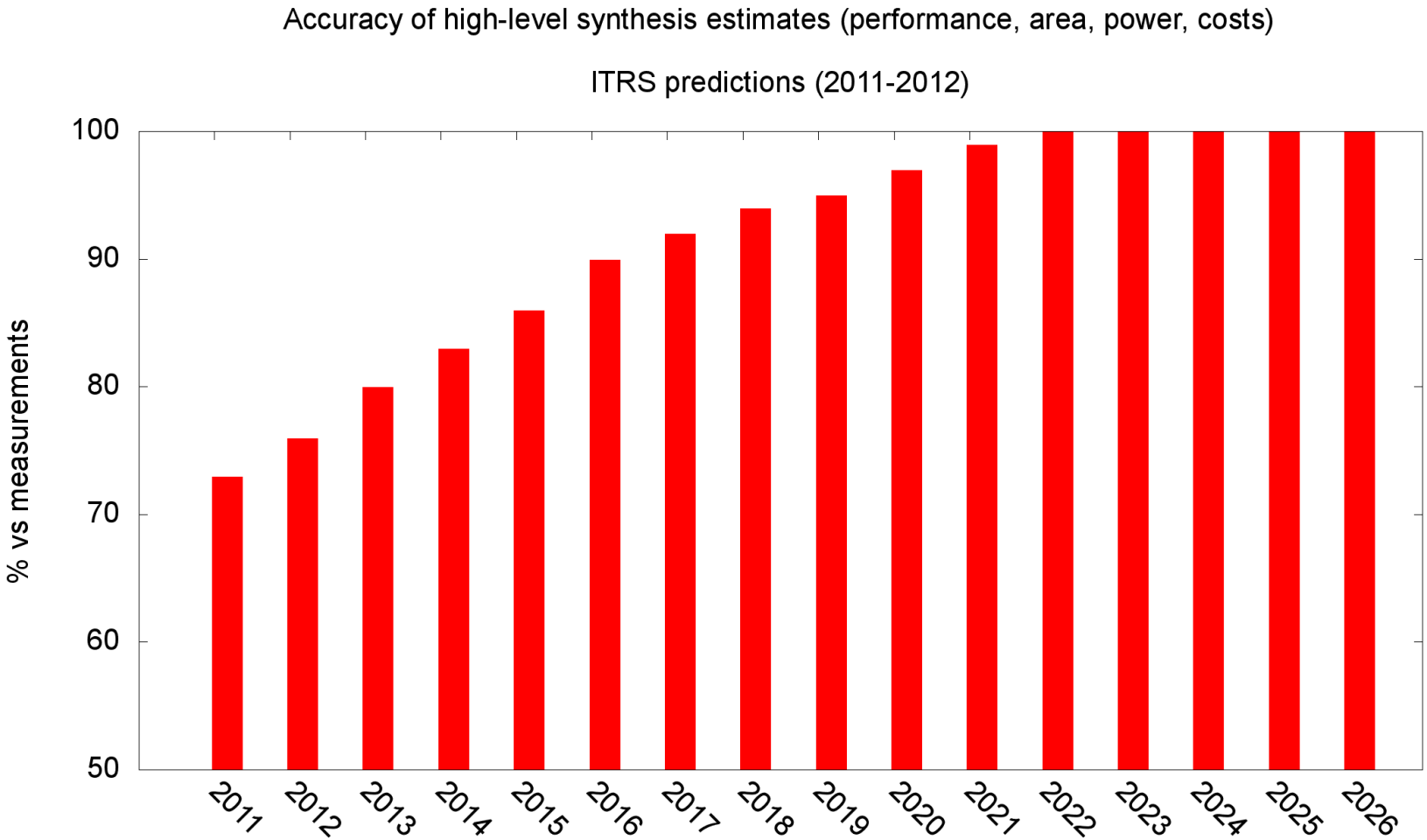
Technology scales exponentially but humans do not



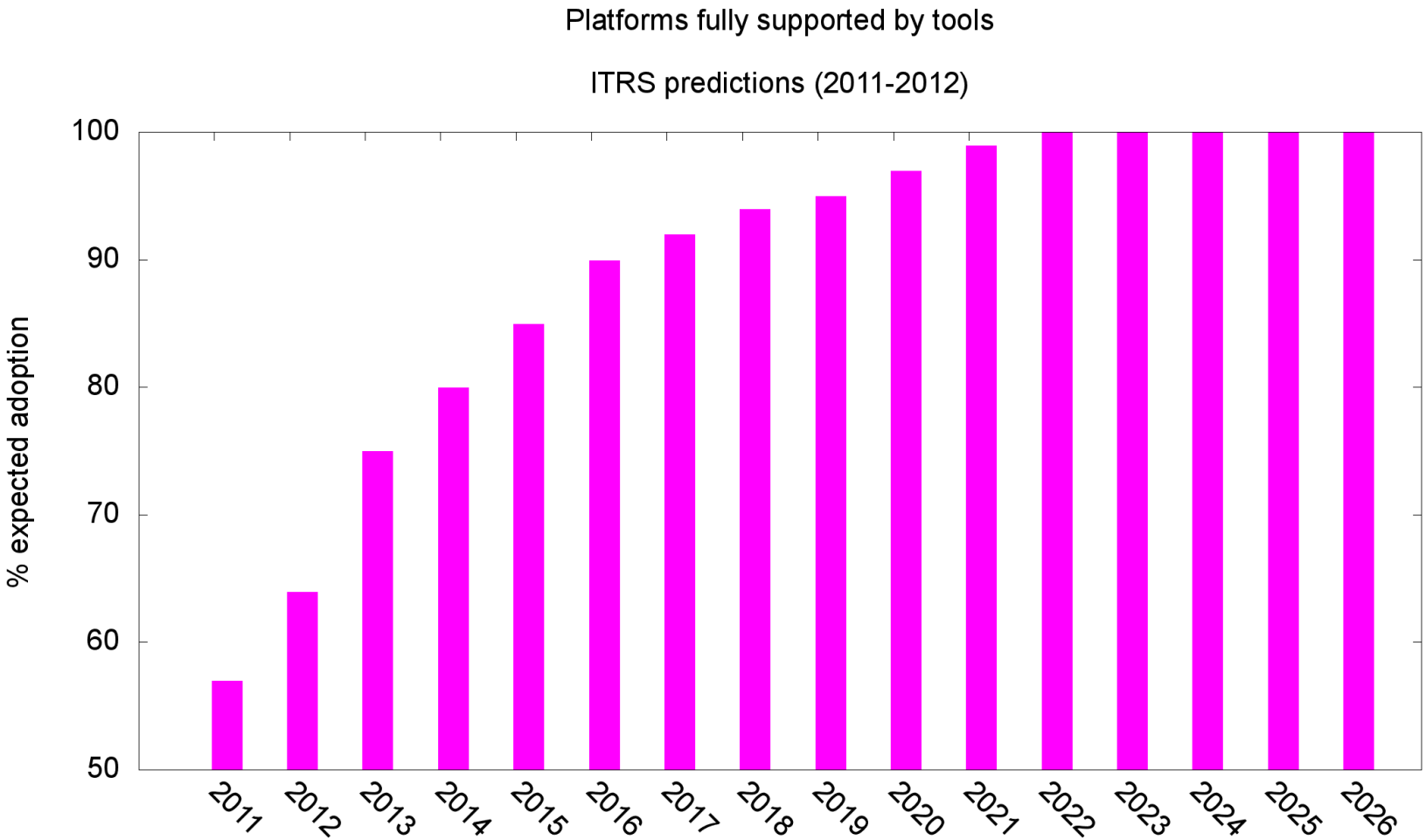
The 2020 digital system: Reducing power by increasing abstraction



The 2020 digital system: Highly-accurate estimators are needed



The 2020 digital system: Tools for all platforms



Hardware development is hard (but why?)

Q These problems have been solved, right?

A No, they have not! They are still open and relevant

- **Technology partner?**
  - Your time-to-market margin is shrinking for each new product
  - You don't have zillions of employees. Your human resources are limited
  - Eventually you will run onto your monetary ceiling
  - If you don't act now, you will be overriden by competition which uses novel approaches
- **Investor?**
  - EDA (Electronic Design Automation) is a great market
  - Steady growth of 10-15% per year
  - EDA is core technology in rapidly growing markets such as mobile, medical, space, robotics
  - Greece lags far behind; high-tech mid-scale production is strategic

High-level synthesis (HLS) comes to the rescue

- Adoption of a high-level design and synthesis methodology imposing user entry from a raised level of abstraction
  1. Hide low-level, time-consuming, error-prone details
  2. Drastically reduce human effort
  3. End-to-end automation from concept to production

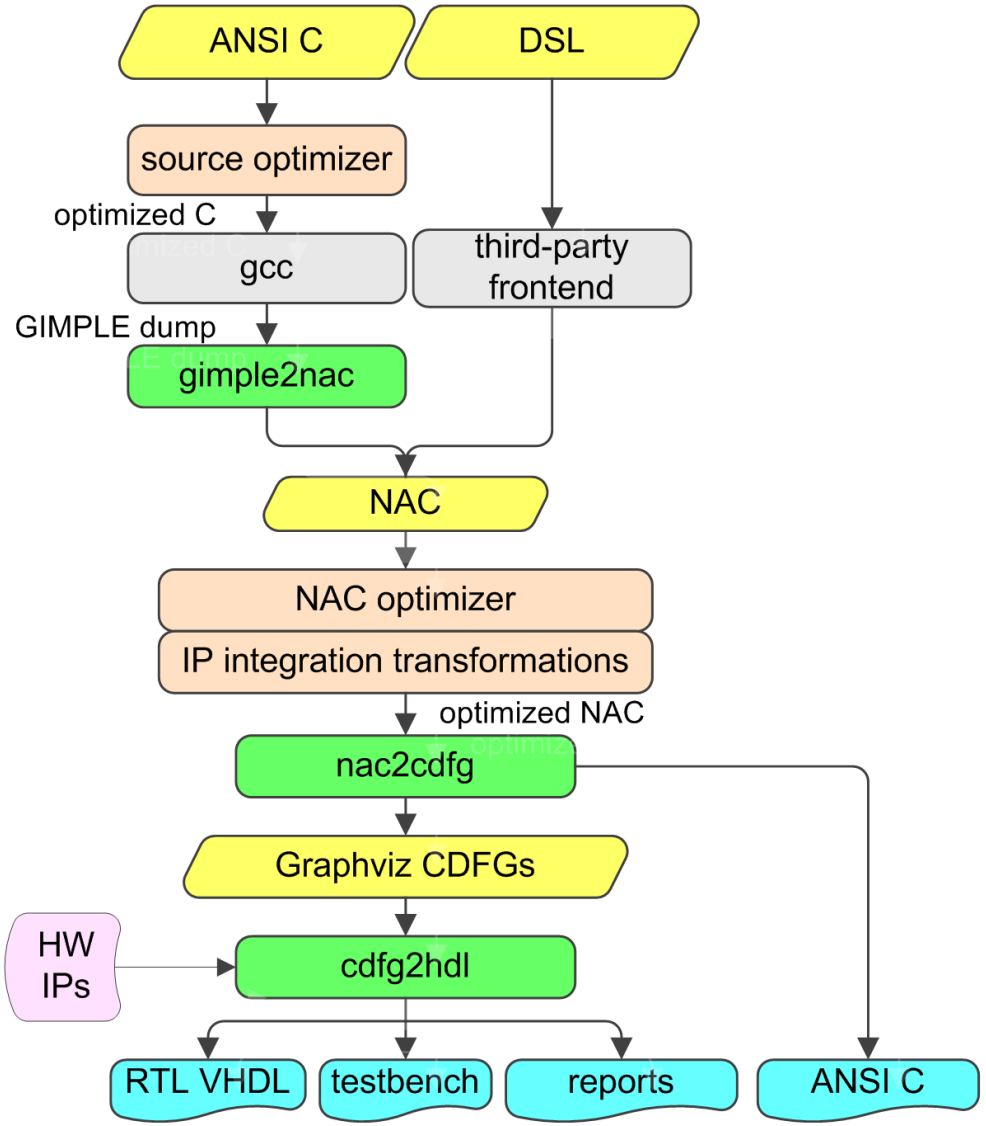
HLS An algorithmic description is automatically synthesized to a customized digital embedded system

- **HercuLeS**: An easy to use HLS environment
- Targets both hardware and software engineers/developers
  1. ASIC/SoC developers, FPGA-based/prototype/reference system engineers
  2. Algorithm developers (custom HW algorithm implementations)
  3. Application engineers (application acceleration)

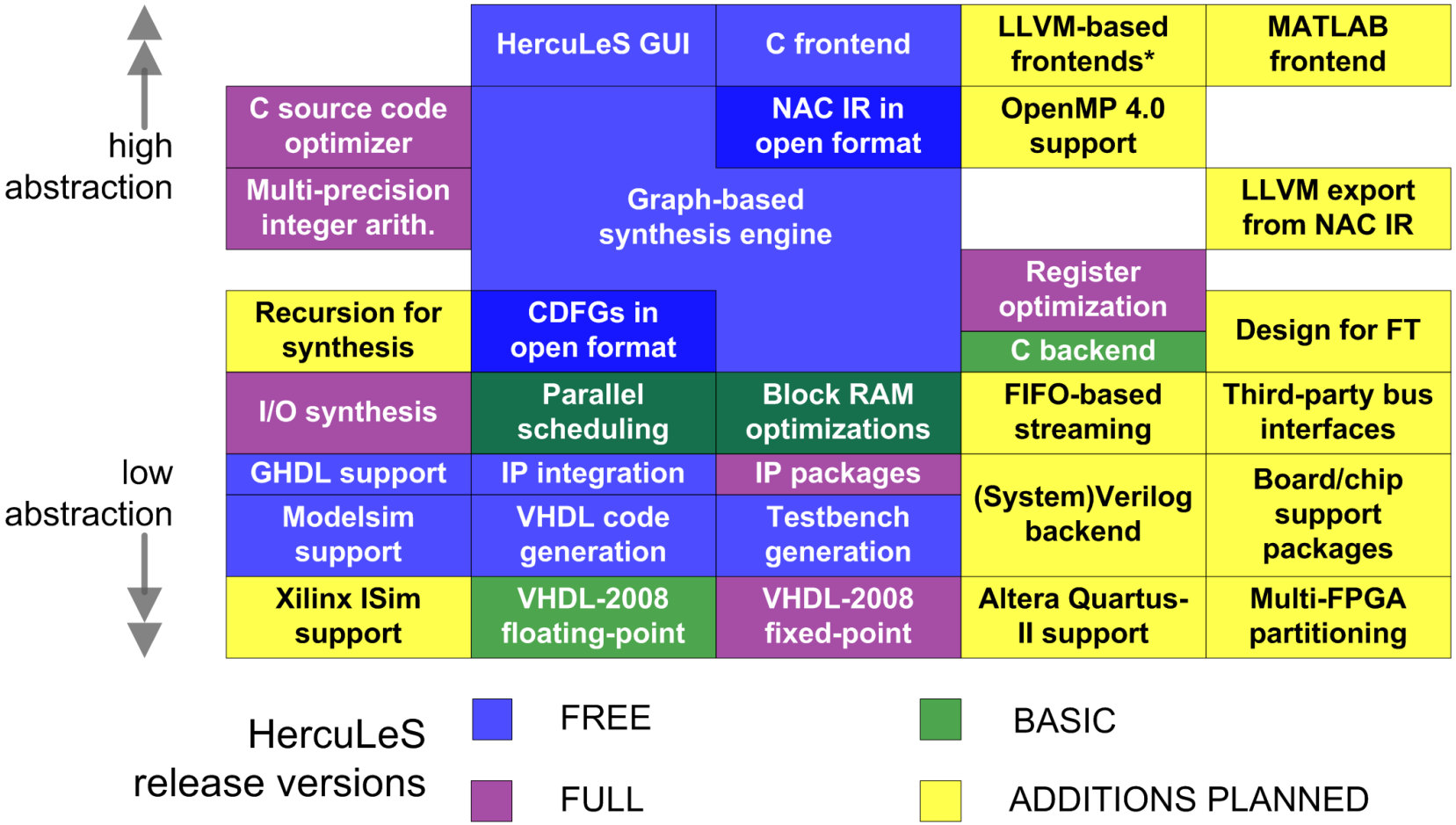
Five things we already do better than competition

1. Competition tools cannot be extended
   - In HercuLeS new frontends (e.g. for domain-specific languages), analyses and optimizations are easy to add
2. Insufficient and opaque representations
   - HercuLeS uses open specifications and formats
   - Its intermediate representation is NAC, a universal typed-assembly language
   - Program graphs expressed in the open Graphviz format
3. Automatic character I/O, dynamic memory allocation and GMP arithmetic are not supported
   - HercuLeS is the first HLS tool to support these features
4. Mandating the use of code templates
   - HercuLeS does not rely on code templates since it uses a graph-based backend
5. Succumbing to vendor and technology dependence
   - The generated HDL is human-readable and vendor- and technology-independent; portable across FPGA and ASIC

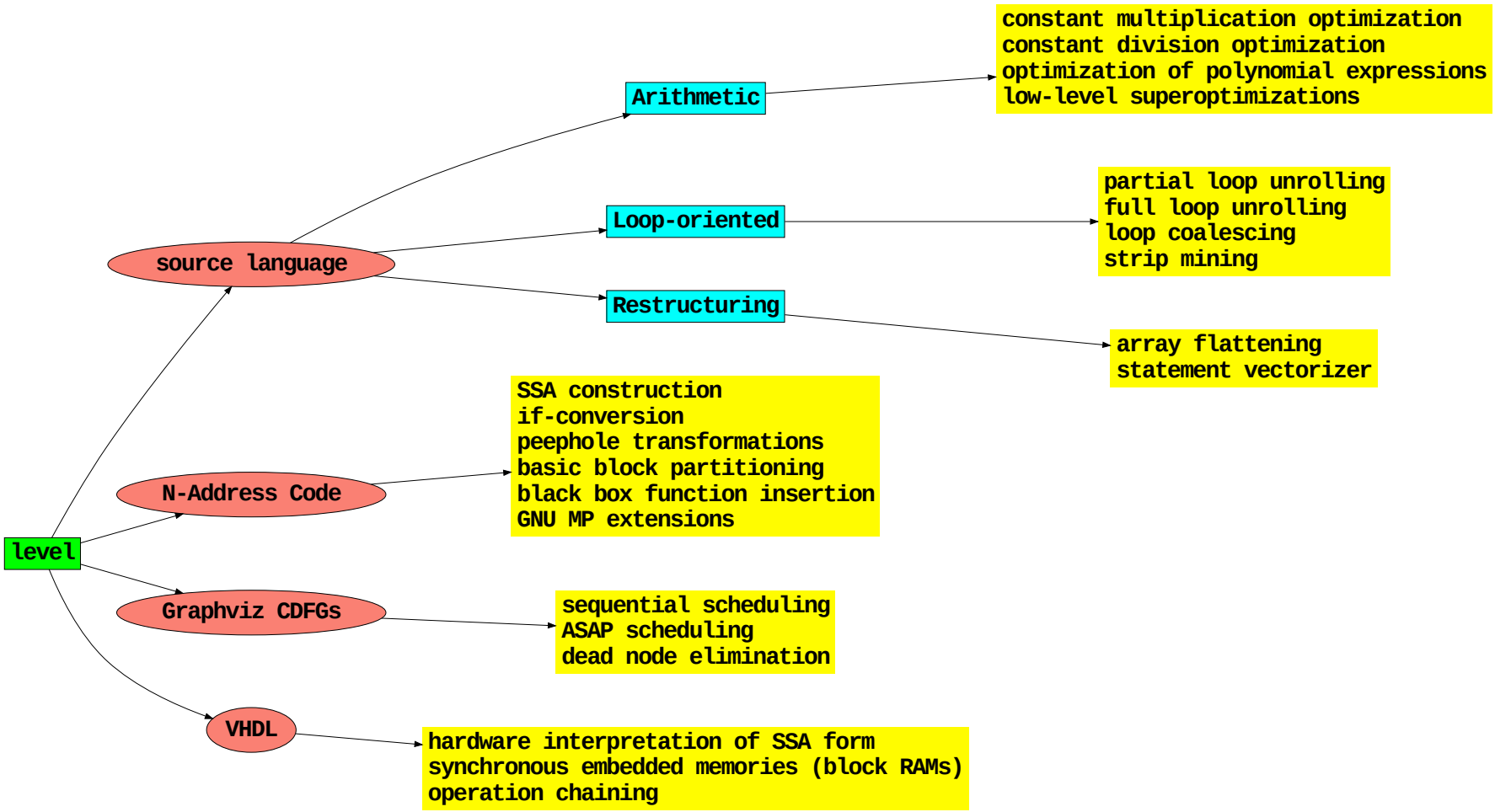
The HercuLeS flow



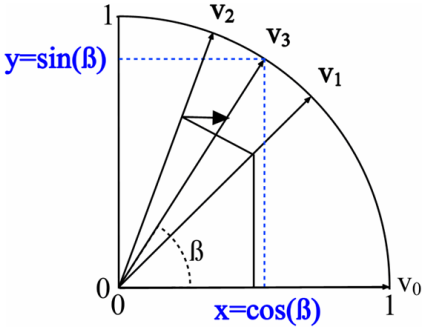
Features


high abstraction
low abstraction
HercuLeS GUI
C frontend
LLVM-based frontends*
MATLAB frontend
C source code optimizer
NAC IR in open format
OpenMP 4.0 support
Multi-precision integer arith.
Graph-based synthesis engine
LLVM export from NAC IR
Register optimization
Recursion for synthesis
CDFGs in open format
C backend
Design for FT
I/O synthesis
Parallel scheduling
Block RAM optimizations
FIFO-based streaming
Third-party bus interfaces
GHDL support
IP integration
IP packages
(System)Verilog backend
Board/chip support packages
Modelsim support
VHDL code generation
Testbench generation
Xilinx ISim support
VHDL-2008 floating-point
VHDL-2008 fixed-point
Altera Quartus-II support
Multi-FPGA partitioning
HercuLeS release versions
FREE
BASIC
FULL
ADDITIONS PLANNED

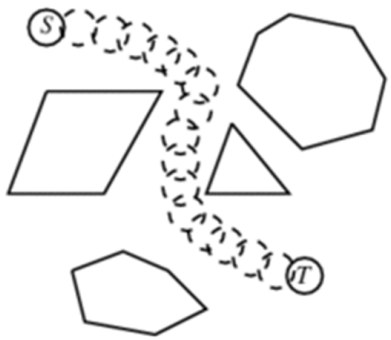
The optimization space of HercuLeS



IPs generated by HercuLeS

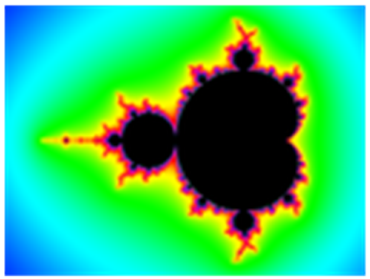


Approximations

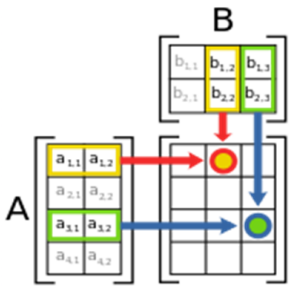


Path planning

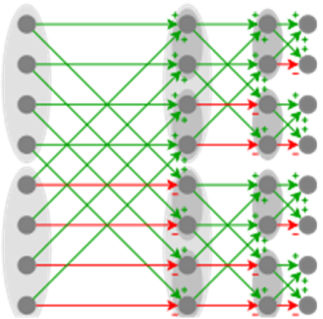
Pattern matching



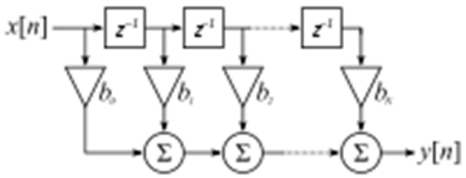
Graphics



Matrix processing



Transforms



Filters

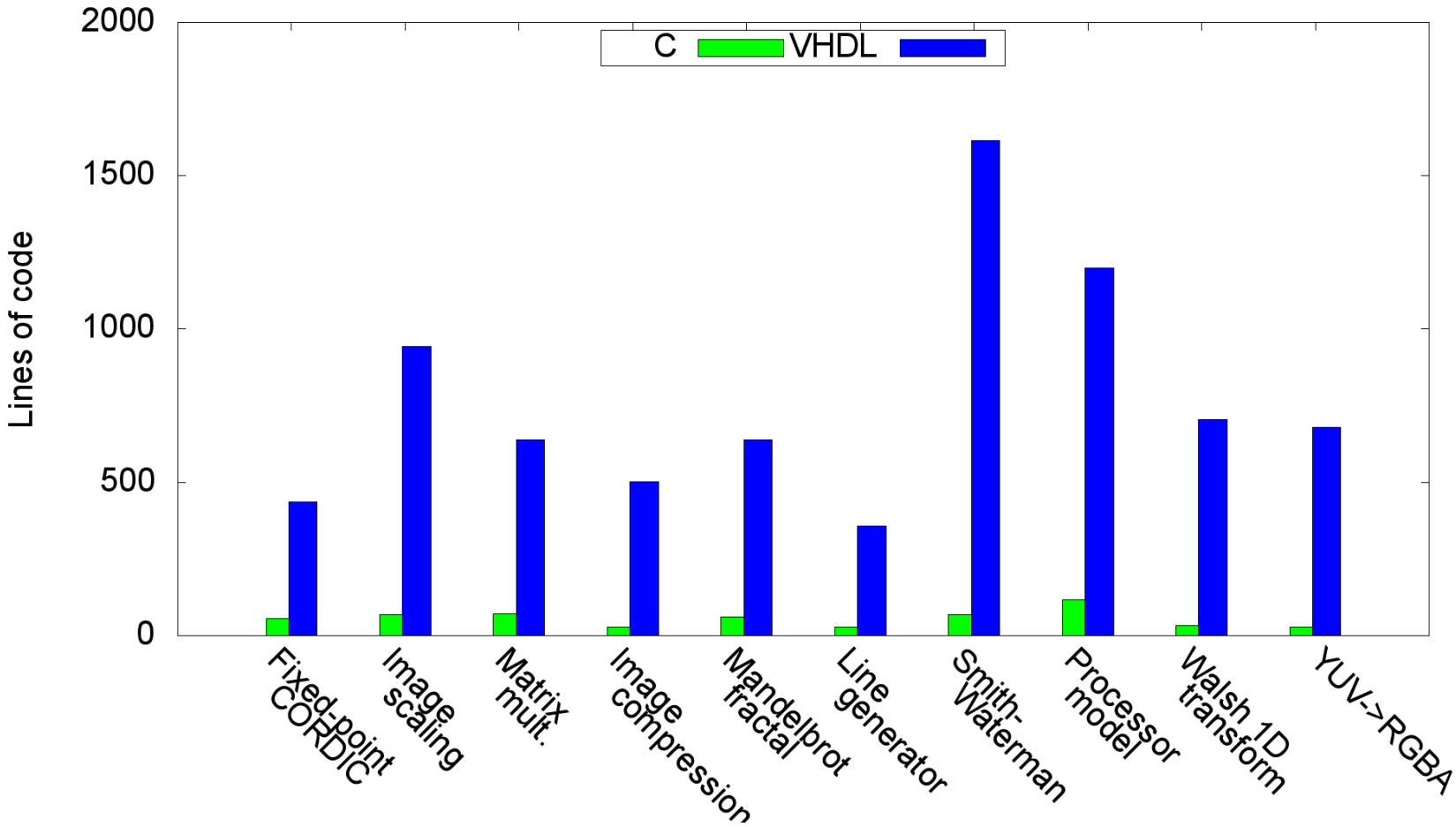
$$X_{\mathbf{k}} = \sum_{\mathbf{n}=0}^{\mathbf{N}-1} e^{-2\pi i \mathbf{k}\cdot(\mathbf{n}/\mathbf{N})} x_{\mathbf{n}}$$

Spectrum analysis

$$x_i^{(k+1)} = \frac{1}{a_{ii}}\left(b_i - \sum_{j=1, i\neq j}^{n} a_{ij} x_j^{(k)}\right)$$

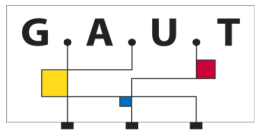
Linear systems

More than 10x productivity increase!



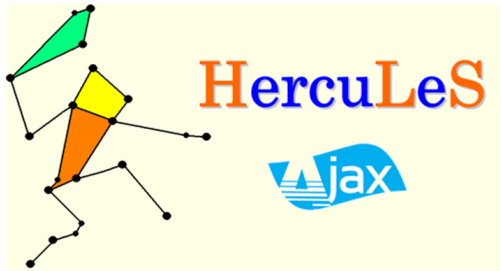
The HLS landscape

cadence CyberWorkBench®



LegUp

SYNOPSYS®



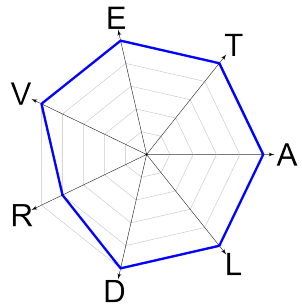
Jacquard COMPUTING INC

XILINX ALL PROGRAMMABLE™

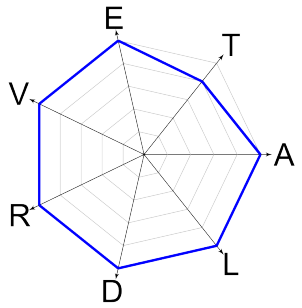
bluespec®

Calypto Catapult®

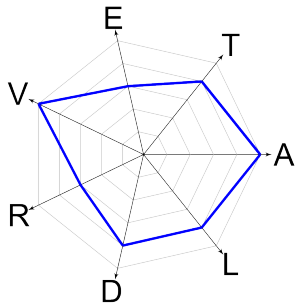
HLS tools comparison (Abstraction; Types; Explore; Verify; Results; Documentation; Learning)



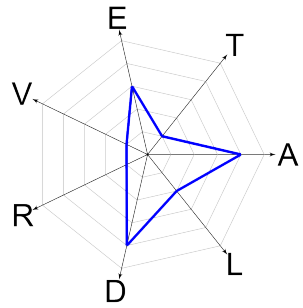
CatapultC



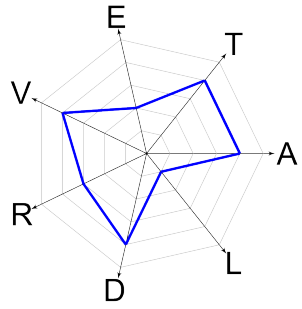
Vivado HLS



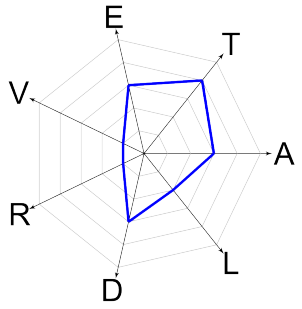
Synphony C



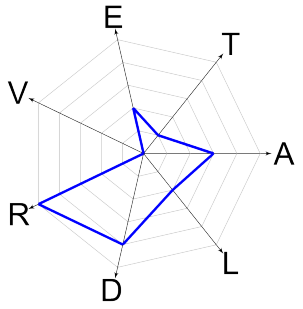
ROCCC



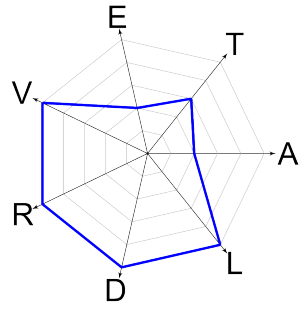
C-to-Silicon



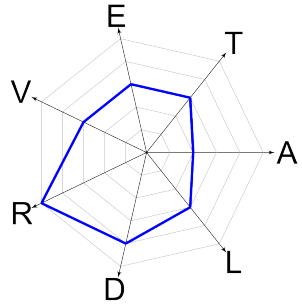
ImpulseC



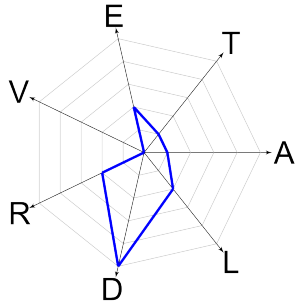
Bluespec



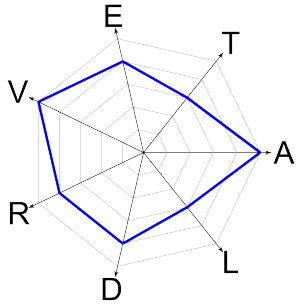
System Generator



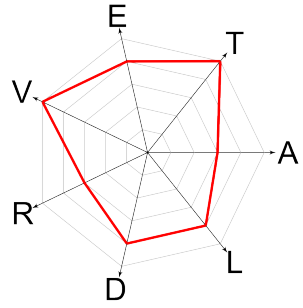
GAUT



SPARK



LegUp



HercuLeS

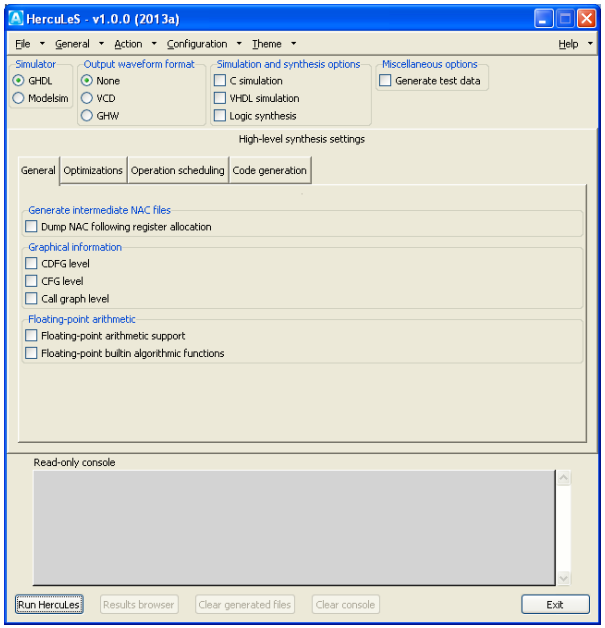
Against competition

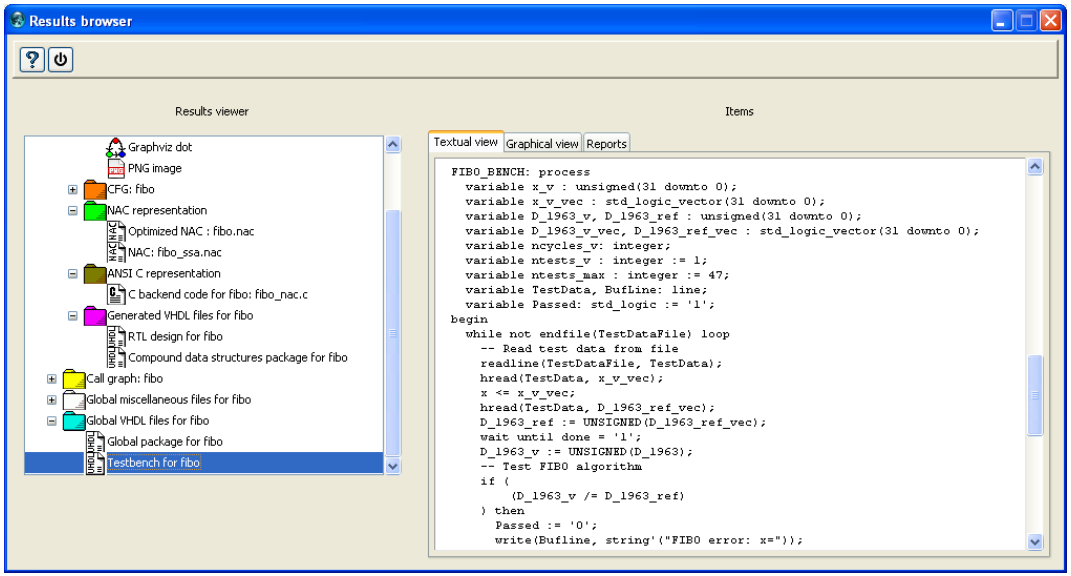
- Preliminary results against Vivado HLS 2013.2 on Virtex-6 and/or Kintex-7 (∗ KC705 development board; XC7K70TFBG676-2 FPGA device)

Benchmark	Vivado HLS			HercuLeS		
	LUTs	Regs	Time (ns)	LUTs	Regs	Time (ns)
∗Array sum	**83**	**172**	**60.5**	164	205	68.327
Bit reversal	67	**39**	72.0	**42**	40	**11.6**
∗Radix-2 division	**218**	**226**	63.6	318	332	**30.6**
Edge detection∗	**246**	**130**	1636.3	680	361	**1606.4**
Fibonacci series	138	**131**	**60.2**	**137**	197	102.7
FIR filter	**102**	**52**	**833.4**	217	140	2729.4
∗FIR filter	**89**	**114**	1027.1	606	540	**393.8**
Greatest common divisor	210	98	**35.2**	**128**	**93**	75.9
Cubic root approx.	**239**	207	**260.6**	365	**201**	400.5
Population count	**45**	**65**	**19.4**	53	102	26.1
Prime sieve∗	525	595	6108.4	**565**	**523**	**3869.5**
∗Sierpinski triangle	**130**	296	**10538.2**	206	**227**	22402.9

The HercuLeS GUI

- Bundled with HercuLeS v1.0.0 (2013a) released on June 30
- Specify code generation, simulation and synthesis options
- Includes embedded results viewer





Summary

- HercuLeS is an extensible HLS environment for hardware and software engineers
  - Straightforward to use from ANSI C, generic assembly (NAC) or custom DSLs to producing compact VHDL designs with competitive QoR
  - Product information
    - HercuLeS GUI for specifying code generation, simulation and synthesis options
    - Commercial distribution: `http://www.ajaxcompilers.com`
    - Technical details: `http://www.nkavvadias.com/hercules/`
    - **FREE** version available: `http://www.nkavvadias.com/temp/index.php`
    - **FREE**, **BASIC**, and **FULL** software licensing schemes (2013.a version)

Thank you

for your time and interest!