Ada as a Foundation Programming Language: Starting Off on the Right Foot

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What's a Foundation Programming Language?

- Introduced in first or second course in undergrad curriculum ("CS1" or "CS2", in educator shorthand)
- (Usually) the first language students learn
- Introduced early enough to serve as a foundation for the rest of the curriculum
- A good foundation language helps student "start off on the right foot"

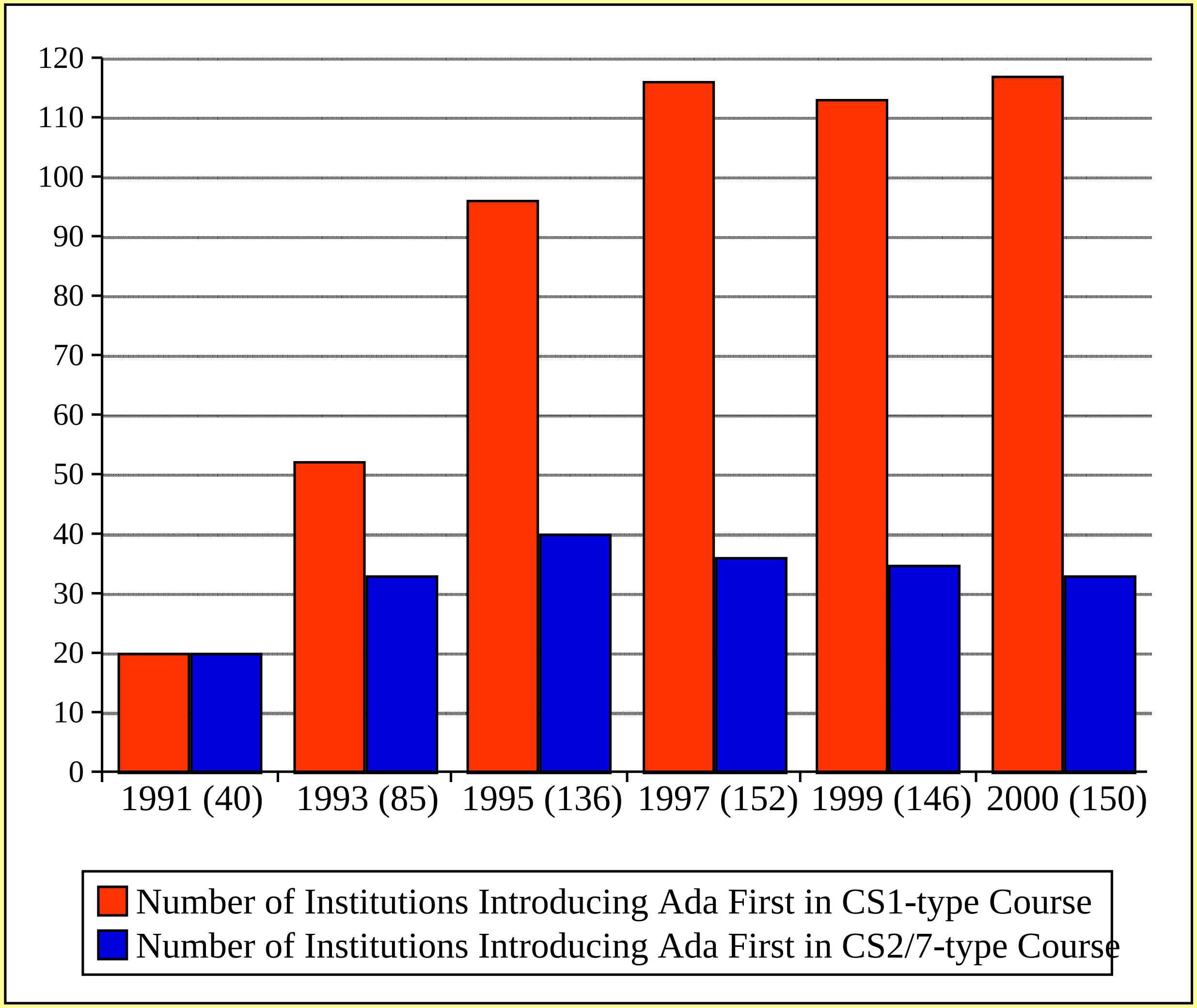
Why Ada as the Foundation Language?

- the disciplined control and data structures of Pascal
- modeling of scalar data (scalar subtypes)
- system composition structures (private types, packages, exceptions, generics, concurrency) derived from Simula, Clu, CSP
- classification structures in Ada 95 are an easily understood extension of the existing type and package structures
- a standard that is taken seriously—provides portability, and sets a good example of professionalism and maturity in the software field
- GNAT is a *very* friendly compiler!

How Does the Foundation Language Get Chosen?

- Faculties usually *vote* on curriculum decisions.
- There are always fads, bandwagons, factions, speculations, etc., just like any other political process.
- Smaller departments are easier to work with, simply because fewer “yes” votes are required to pass something.
- As in Congress, in a faculty it is difficult to make something happen but easy to make it *not* happen.

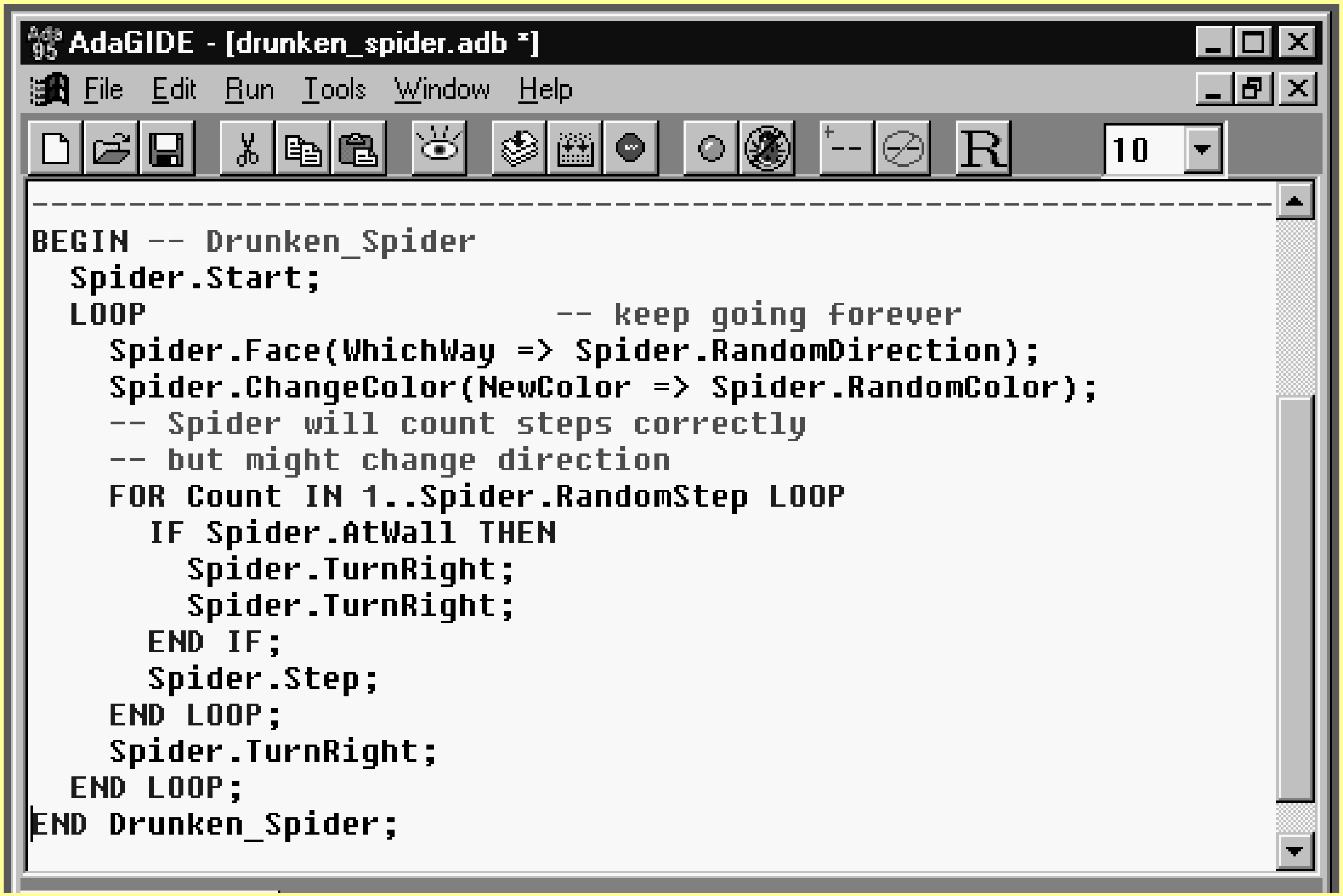
Ada as a Foundation Programming Language



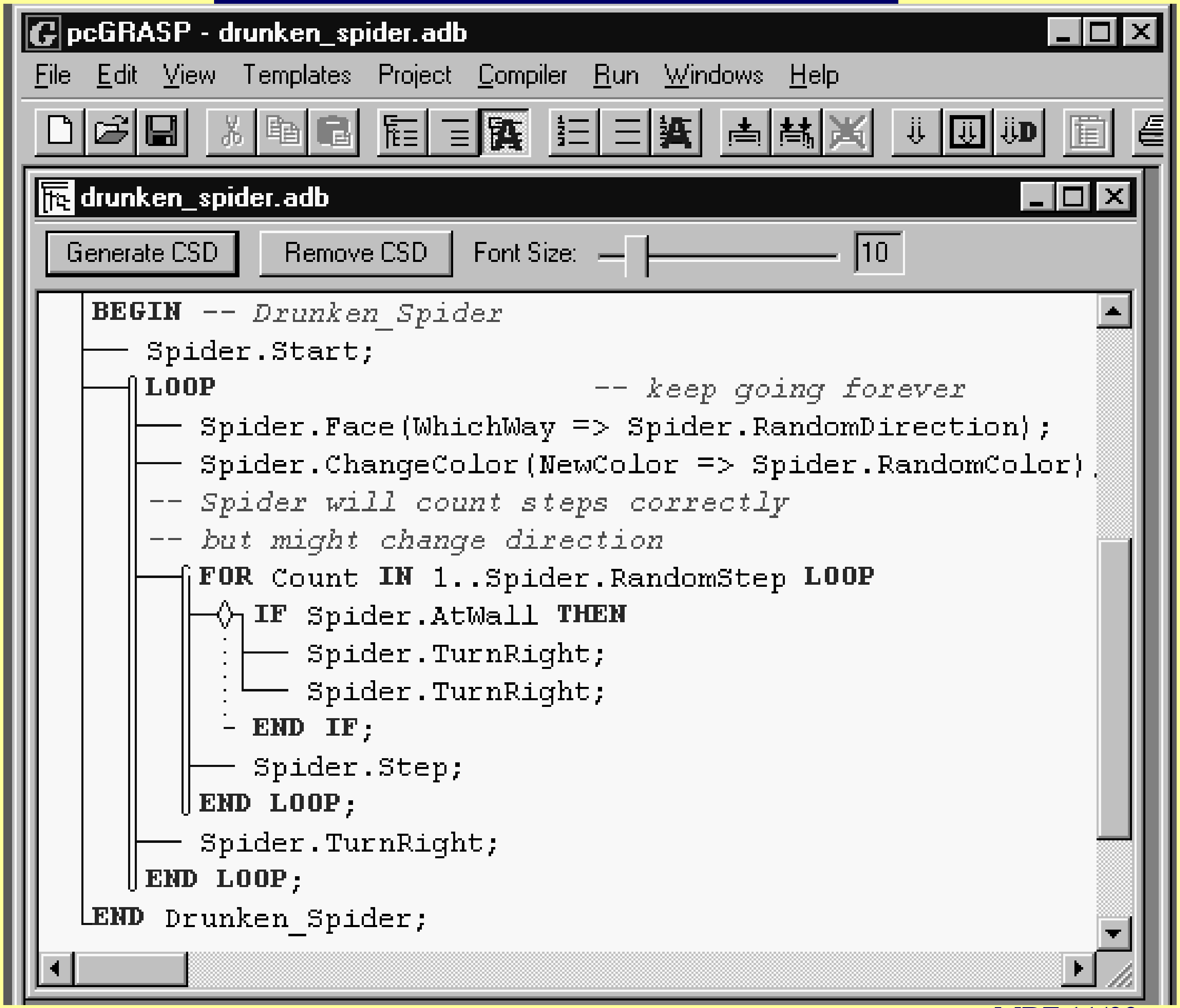
Continuing Innovation in Ada Foundation Courses

- New textbook editions:
  Feldman/Koffman (1999); Dale/Weems/McCormick (2000).
- AdaGIDE and GRASP GUIs both contain “beginner-friendly” features.
- University of Northern Iowa: switched *from* C++ *to* Ada. Local industry really likes the recent graduates, even for C++ projects.
- British Columbia Institute of Technology adopted Ada this year as foundation language.
- U.S. Air Force Academy is starting to use Ada in all-freshmen course to program LEGO Mindstorm robots.
- George Washington University research in introducing concurrent programming into a CS1-level course. (2 doctoral dissertations so far.)

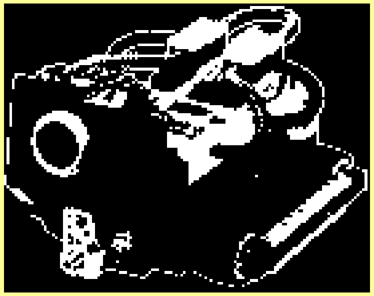
AdaGIDE (U.S. Air Force Academy)

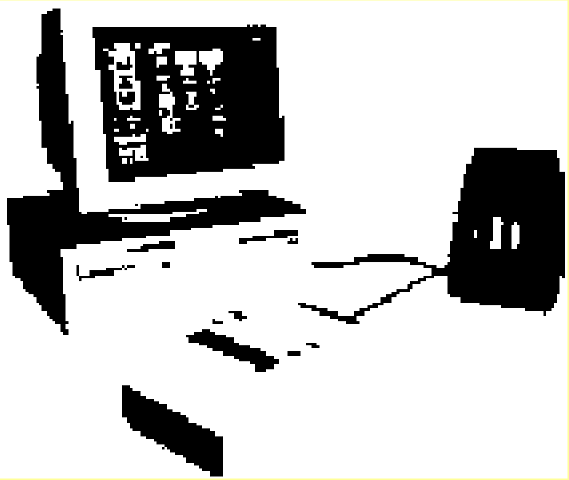


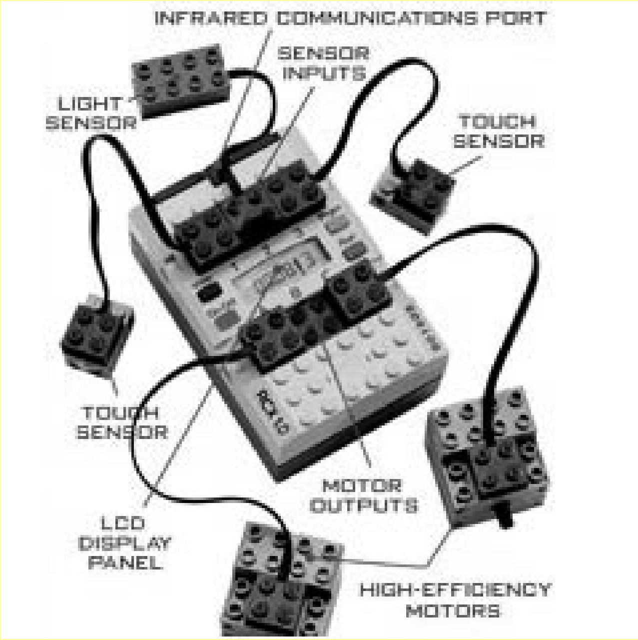
GRASP (Auburn University)



LEGO Mindstorms at U.S. Air Force Academy







GW Computer Science Education Research: Should We Teach Concurrency in Intro Courses?

- Language sophistication is making it possible to do—concurrency primitives are no longer “low level” and OS-dependent
- Some educators opine that because the world is concurrent, concurrency is not hard for beginners to understand
- Some opine that if students learn concurrency early, they won’t be stuck in a sequential “von Neumann bottleneck”
- A possible downside: “conservation of curriculum”; i.e., making room for concurrency means we may have to give less attention to other introductory subjects
- Caution and controlled experimentation is called for, to try to ensure that introducing a major new subject does not degrade student learning of traditional subjects

GW's Introductory Software Development Course for CS Majors

`http://www.seas.gwu.edu/~csci51`

- Csci 51, Introduction to Software Development
- Catalog Description:

  Introduction to the solution of problems on a digital computer using Ada. Structured programming concepts; proper documentation techniques; efficiency of programs; design of test data. Writing, debugging, and running programs in an interactive computing environment.

- 3 credits: 2.5 clock hours lecture; 1.5 clock hours laboratory per week

CSci 51 Demographics, Spring 2000

- Number of students: 79
  Students claiming previous programming experience: 31 (39%)
- Students indicating they were CS majors: 51 (64%)
  CS majors claiming previous programming experience: 22 (43%)
- Number of females: 19 (25% of population)
  Females with previous experience: 9 (47% of females)
  Female CS majors: 12 (23% of CS majors)
  Female CS majors with previous experience: 4 (33%)
- In most semesters, a student's position on the final grade curve is essentially independent of major or previous experience
- In most semesters, the withdrawal rate is no more than about 25% (this is low for typical CS1 courses)

GW's Introductory Software Development Course for CS Majors

- Course was taught with Pascal 1980-92, Ada 83 1992-95, Ada 95 1995-present
- Students complete a small lab exercise in each lab
- Students complete (typically) 8 software development projects, 1-2 weeks each
- "Spider"—simple turtle-graphics-type alogithm animation—used at start of course to teach algorithms, control structures, and exception handling
- GNU Ada 95 (GNAT) compiler used; default platform is Solaris but students can install on Mac, Linux, Windows
- Default Spider is simple 24 x 80 monochrome, but high-resolution color provided for Windows, Mac

A Spider Program

```
WITH Spider;
PROCEDURE Spiral IS
BEGIN -- Spiral
  Spider.Start;
  Spider.Face(WhichWay => Spider.RandomDirection);

  -- draw ten lines, starting in a random direction
  FOR Line IN 1..10 LOOP
    Spider.ChangeColor(NewColor => Spider.RandomColor);

    -- inner loop takes its bound from outer count
    FOR Count IN 1..Line LOOP
      Spider.Step;
    END LOOP;

    Spider.TurnRight;
  END LOOP;
  Spider.Quit;
END Spiral;
```

Spider Program Running

```
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| v |        |. . . . . . . . . . . . . . . . . . . .|
| . |        |. . . . . . . . . . . . . . . . . . . .|
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             |. . . . . . . . . . . . . . . . . . . .|
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             |. . . . . B . . . . . . . . . . . . . .|
             |. . . . . B . . . . . . . G . . . . . .|
             |. . . . . B . K . . . . . G . . . . . .|
             |. . . . . B . K . K K B . G . . . . . .|
             |. . . . . B . K . G . B . G . . . . . .|
             |. . . . . B . K . . . B . G . . . . . .|
             |. . . . . B . K . . . . . G . . . . . .|
             |. . . . . B . . . . . . . G . . . . . .|
             |. . . . . B R R R R R R R R . . . . . .|
             |. . . . . . . . . . . . . . . . . . . .|
             |. . . . . . . . . . . . . . . . . . . .|
             |. . . . . . . . . . . . . . . . . . . .|
             |. . . . . . . . . . . . . . . . . . . .|
             |. . . . . . . . . . . . . . . . . . . .|
              ---------------------------------------
```
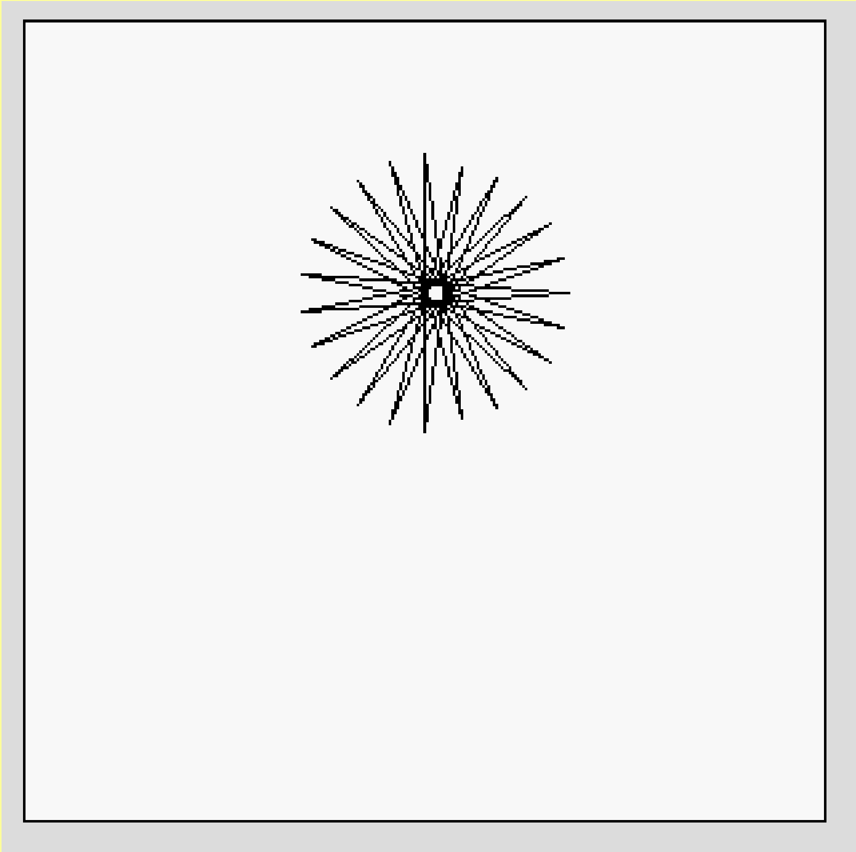

High-Resolution Polystars

```
WITH Spider_Hires; USE  Spider_Hires;
PROCEDURE Polystars IS
  PROCEDURE Polystar(Length: IN Steps; Sides: IN Positive) IS
  BEGIN
    FOR Side IN 1..Sides LOOP
      Step(HowMany => Length);
      TurnRight(HowFar => 180.0 - 180.0/Float(Sides));
    END LOOP;
  END Polystar;
BEGIN -- Polystars
  SetSpeed(Slow);
  FOR Count IN 3 .. 25 LOOP
    IF Count REM 2 = 1 THEN
      Start;
      Polystar(Length => 100, Sides => Count);
      Wait;
    END IF;
  END LOOP;
  Quit;
END Polystars;
```

High Resolution Polystars



Drunken Spider

```
WITH Spider;
PROCEDURE Drunken_Spider IS
BEGIN -- Drunken_Spider
  Spider.Start;
  LOOP                     -- keep going forever
    Spider.Face(WhichWay => Spider.RandomDirection);
    Spider.ChangeColor(NewColor => Spider.RandomColor);
    -- Spider will count steps correctly
    -- but might change direction
    FOR Count IN 1..Spider.RandomStep LOOP
      IF Spider.AtWall THEN
        Spider.TurnRight;
        Spider.TurnRight;
      END IF;
      Spider.Step;
    END LOOP;
    Spider.TurnRight;
  END LOOP;
END Drunken_Spider;
```

Drunken Spider

```
  ---              ---------------------------------------
| v |             |. . . . . . . . . . . . . . . . . . . .|
| G |             |. . . . . . . . . . . . G . . . . . . .|
  ---             |. . . . . . . . . . . . G . . . . . . .|
                  |. . . . . . . . . . . . G . . . . . . .|
                  |. . . . . . . . . . . . G . . . . . . .|
                  |G G G G G G G G G G G G * . . . . . . .|
                  |. . . . . . . . G . . . . . . . . . . .|
                  |. . . . . . . . G . . . . . . . . . . .|
                  |. . . . . . . . G . . . . . . . . . . .|
                  |G G G G G G G G G G G G G G G G G G G .|
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                  |. . G . . . . . G G . . . . . . . . . .|
                  |. . G . . . . . G G . . . . G . . . . .|
                  |G G G G G G G G G G G G G G G . . . . .|
                  |. . . . . . . . G G G G G G G G G G G G|
                  |. . . . . . . . G G . . . . G . . . . .|
                  |. . . . . . . . G G . . . . G . . . . .|
                  |. . . . . . . . G G . . . . G . . . . .|
                  |. . . . . . . . G G . . . . G . . . . .|
                  |. . . . . . . . G G . . . . G . . . . .|
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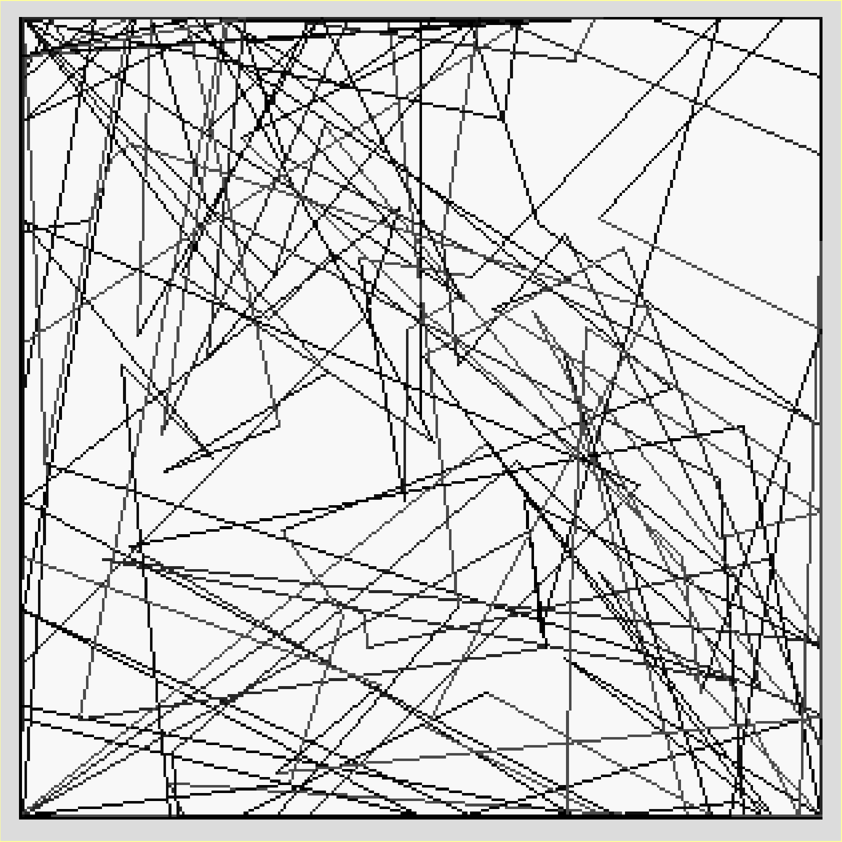
Drunken Spider, High Resolution



Research Studies on Concurrent Programming in Intro Courses

- Bachus, D.Sc.Dissertation 1996. Can we teach concurrent programming (with Ada) to novices? Is concurrency necessarily an advanced topic?
- METHOD: non-credit GW summer course with voluntary students; soldiers at U.S. Army IT training school
- RESULT: Bachus showed that students without much programming experience can understand some fairly sophisticated examples of concurrency

Research Studies on Concurrent Programming in Intro Courses

- Lund, D.Sc. Dissertation 1999. Can we introduce concurrency into a CS1-level course? Will we lose anything by doing so?
- METHOD:

  teach Csci 51 with no concurrency content

  teach it again (twice) with unchanged original content but add concurrency

  measure student outcomes (projects, exams) on both nonconcurrency and concurrency content
- RESULT: Lund showed that we can introduce concurrency with no substantial degradation of outcomes

Typical Final Projects Using Concurrency in Csci 51 (and Csci 131, Algorithms and Data Structures I)

- Simulation of Highway Speed Monitor
- Multiple Drunken Spiders
- Dining Philosophers
- Simulation of a Bank in Operation

Highway Speed Monitor Simulation

```
                              Current time 16:32:05


              Y O U R   S P E E D   I S


                     XX          XXXXX
                XX   XX         XXXXXXX
                XX   XX        XX      XX
                XX   XX        XX      XX
                XX   XX        XX      XX
                XXXXXXXXX       XXXXXXXX
                XXXXXXXXX        XXXXXXX
                     XX                XX
                     XX        XX      XX
                     XX         XXXXXXX
                     XX          XXXXX
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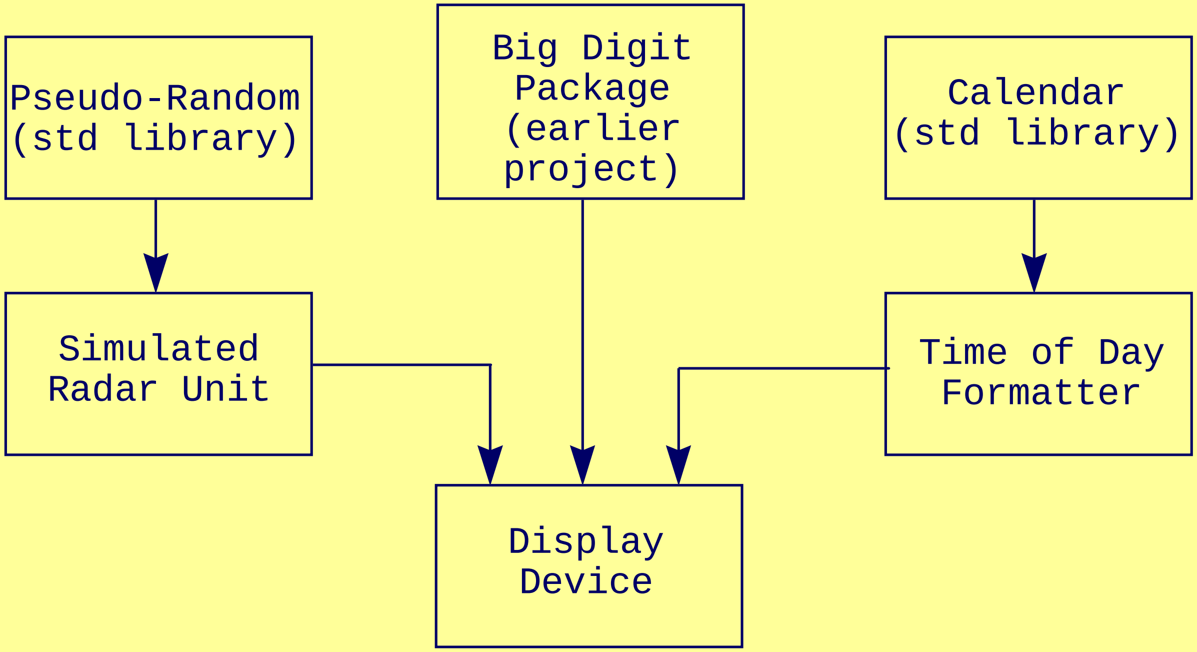
Highway Speed Monitor Simulation



Drunken Spiders Family

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|. . . . . . . . * . . . . . . . . . . .|
|. . . . . . . . . . . . . . . . . . . .|
|. . . . . . . . . . . . . . . . . . . .|
|. . . . . . . . . . . . * . . . . . . .|
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|. . . . . . . . . . . . . . . . . . . .|
|. . . . . . . . . . . . . . . . * . . .|
|. . . * . . . . . . * . . . . . . . . .|
|. . . . . . . . . . . . . . . . . . . .|
|* . . . . . . . . . . . . . . . . . . .|
|. . . . . . . . . . . . . . . . . * . .|
|. . . . . . . . . . . . . . . . . . . .|
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|. . . . . . . * . . . . . . . . . . . .|
|. . . . . . . . . . . . . . . . . . . .|
|. . . . . . . . . . . . . * . . . . . .|
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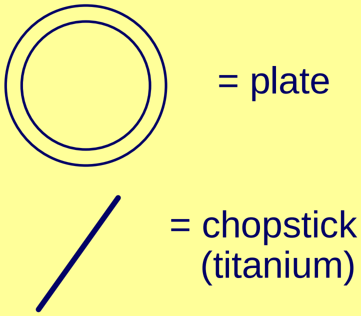
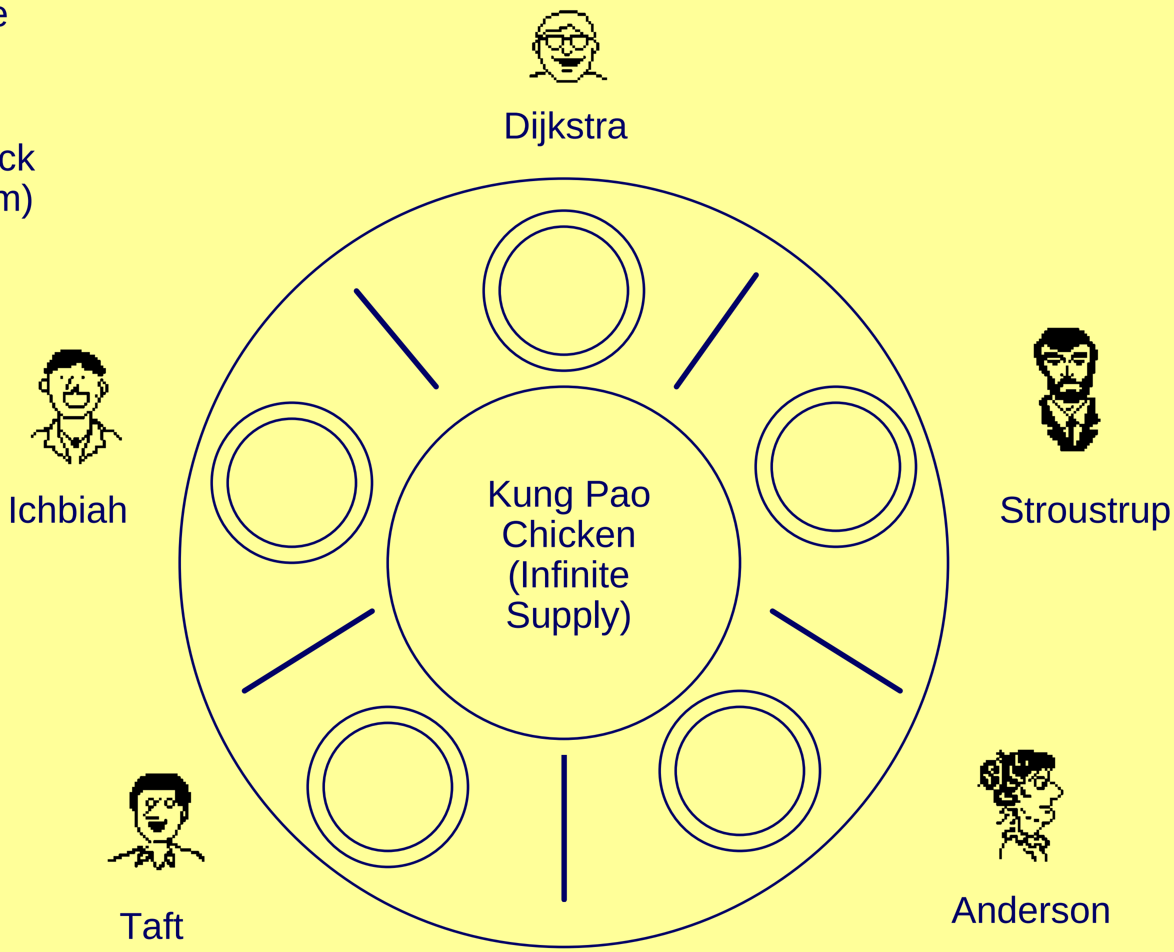
Dijkstra’s Famous Dining Philosophers (1971)





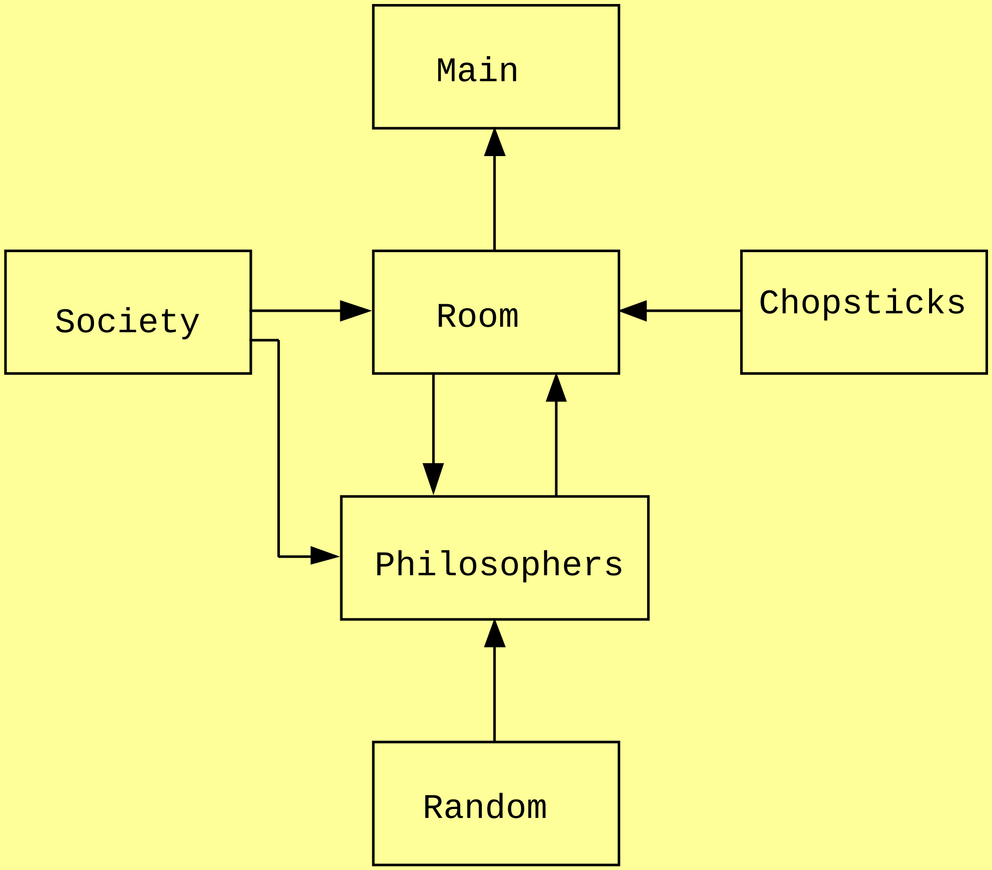
Dining Philosophers

```
                    +----------------------------+
                    |Edsger Dijkstra             |
                    |----------------------------|
                    |T = 13 Meal 1, 5 seconds.   |
                    |T = 18 Yum-yum (burp)       |
                    |T = 18 Thinking 8 seconds.  |
                    +----------------------------+

+----------------------------+             +----------------------------+
|Jean Ichbiah                |             |Bjarne Stroustrup           |
|----------------------------|             |----------------------------|
|T = 14 First chopstick 3    |             |T = 19 Meal 1, 9 seconds.   |
|T = 19 Second chopstick 4   |             |T = 18 First chopstick 1    |
|T = 19 Meal 2, 10 seconds.  |             |T = 19 Second chopstick 5   |
+----------------------------+             +----------------------------+

     +----------------------------+    +----------------------------+
     |Tucker Taft                 |    |Chris Anderson              |
     |----------------------------|    |----------------------------|
     |T = 19 Yum-yum (burp)       |    |T = 18 First chopstick 2    |
     |T = 19 Thinking 4 seconds.  |    |T = 13 Yum-yum (burp)       |
     |T = 9 Meal 2, 10 seconds.   |    |T = 13 Thinking 4 seconds.  |
     +----------------------------+    +----------------------------+
```

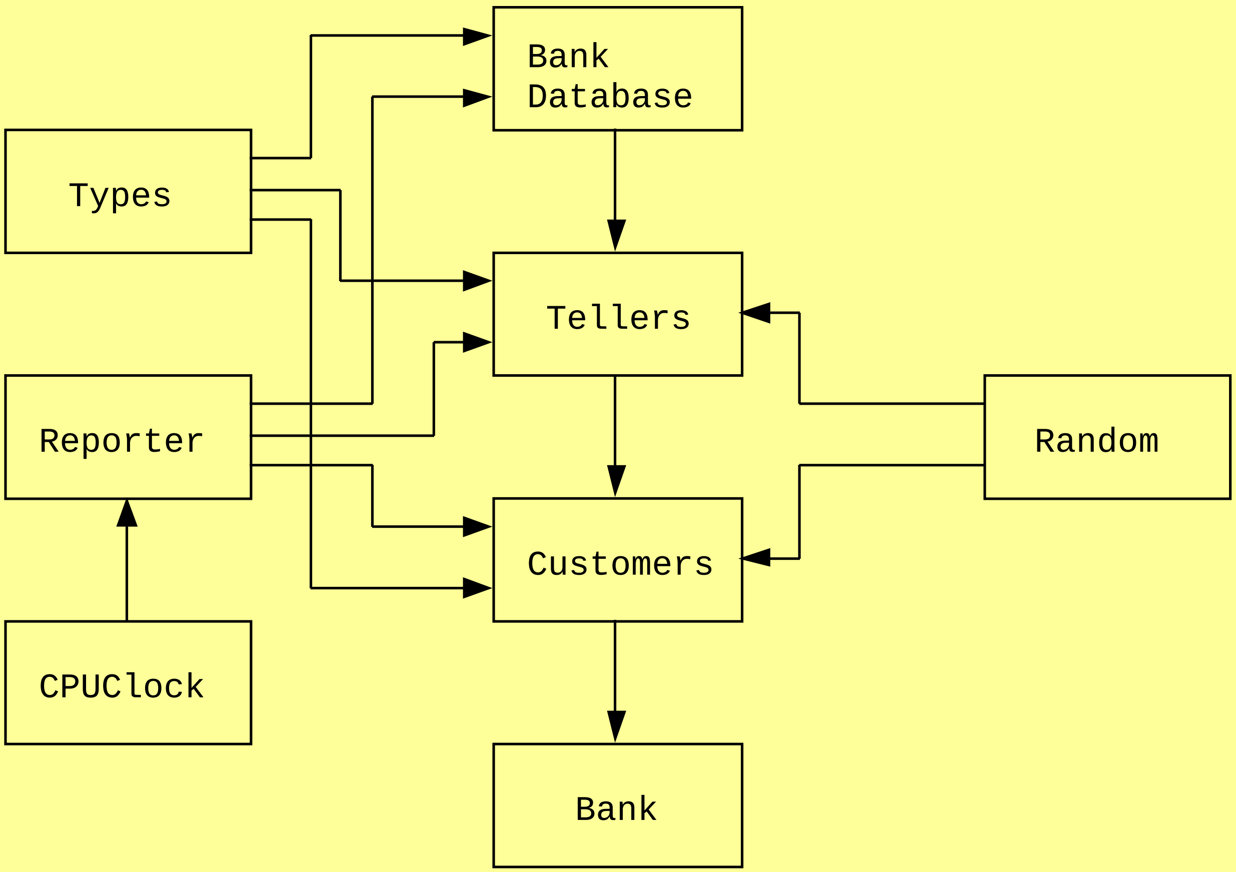
Module Dependencies for Dining Philosophers



Bank Simulation

```
T = 5   Teller B: Transaction will take 4 sec
T = 7   Teller A: Acct 2 - Balance is 0
T = 7   Teller A: Transaction will take 3 sec
T = 7 Account 2 alive.
T = 7 Account 2 will return after 3 sec
T = 9   Teller B: Acct 1 - Balance is 266
T = 10 Account 1 will return after 5 sec
T = 10   Teller A: Acct 3 - Balance is 0
T = 10   Teller A: Transaction will take 4 sec
T = 10 Account 3 alive.
T = 10 Account 3 will return after 3 sec
T = 10 Account 2 depositing 266 with Teller B
T = 10   Teller B: Transaction will take 1 sec
T = 11   Teller B: Acct 2 - Balance is 266
T = 12 Account 2 will return after 5 sec
T = 13 Account 3 depositing 266 with Teller B
```

Module Dependencies for Bank Simulation



Conclusions

- Material in foundation courses must be handled with care; students must complete the course well-prepared for the rest of the courses in their program
- GW *seniors* study Ada, Java, C, C++, and lots of other stuff in their four years. They tell us they are glad they began their program with Ada.
- The jury is still out on concurrency in intro courses but we are starting to understand the issues
- Computer Science Education research is challenging but rewarding