Dr Trevor Young
Mechanical and Aeronautical Engineering
University of Limerick
Ireland

Design, Build and Fly:
An approach to Teaching Aircraft Design

European Workshop on Aircraft Design Education (EWADE)
Sevilla: 13 – 15 May 2009

Outline

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1. Introduction
2. The AIAA DBFcompetition
3. DBF at University of Limerick (UL)
4. Lessons learnt
5. Concluding remarks

Design, Build and Fly:

An approach to Teaching Aircraft Design

European Workshop on Aircraft Design Education (EWADE)
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Introduction

Design, Build & Fly: The sequel

- The presentation is a follow-on to the Samara presentation
- Recap on the AIAA DBF competition
- UL's experience over the past three years
- Concluding remarks

Fig. *DBF flight test (January 2009)*

The AIAA DBF competition

AIAA's DBF competition

- Student contest organized by the AIAA, with industry support from Cessna and Raytheon Missile Systems (formerly, the Office of Naval Research).
- Teams compete by designing, building and flying an electric, radio controlled (r/c) aircraft to meet a specification (range, endurance, payload, speed etc.).

Fig. *AIAA's DBF website*

- Stated goal: It is an engineering challenge – not a model airplane contest.
- The winner is determined by the best combination of
  - written report;
  - flight performance; and
  - overall design.

The AIAA DBF competition

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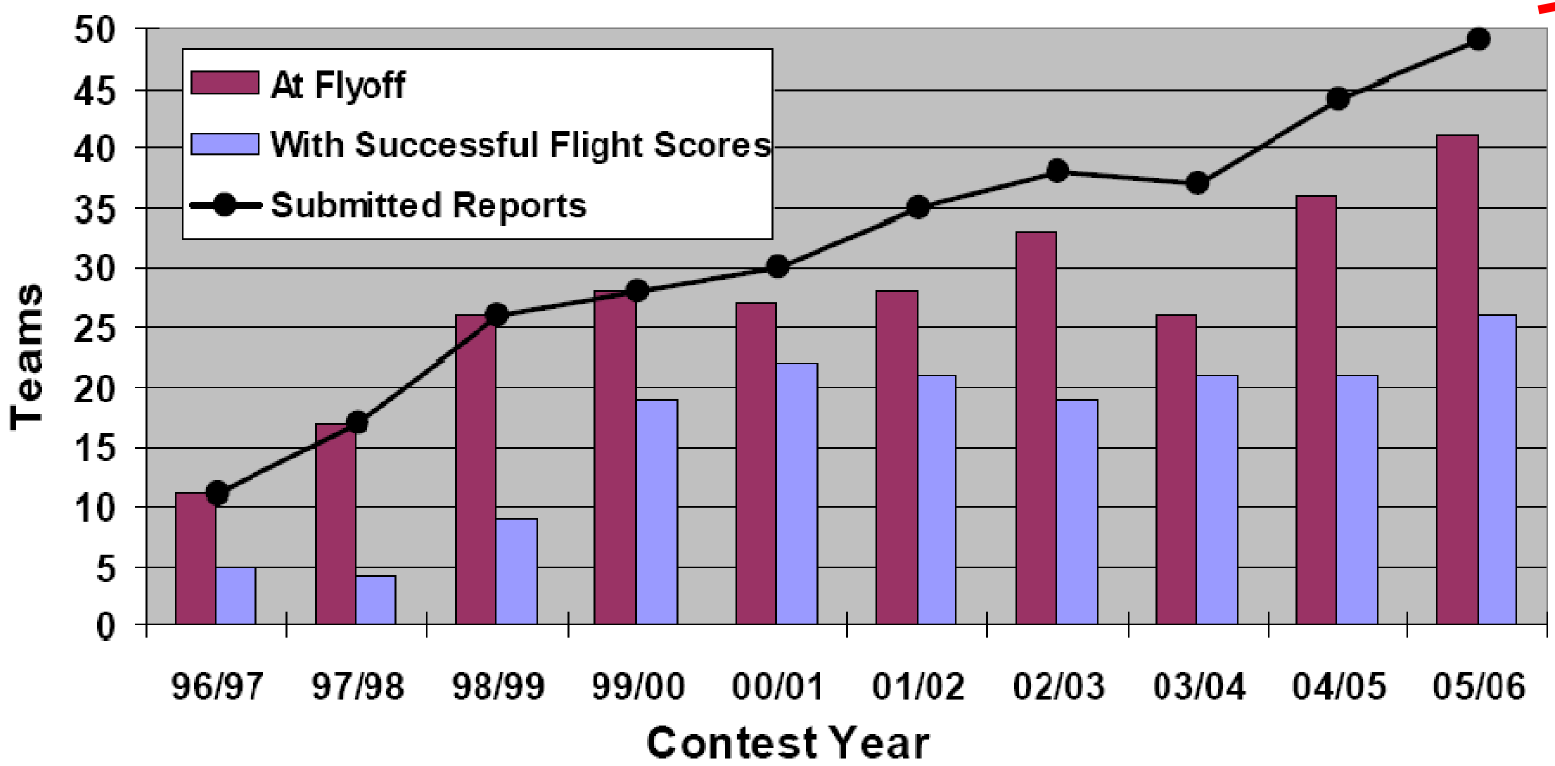
AIAA's DBF competition

Competition history

- Running for 13 years.
- > 50 teams in recent years



> 50 teams in recent years

Ref: Bovais, *et al.* (2006).

The AIAA DBF competition

AIAA's DBF competition

Typical timetable

- Rules posted: August
- Entry deadline: October
- Report submission: March
- Flight test: April

Cash prizes

$2500 for 1st
$1500 for 2nd
$1000 for 3rd

Fig. 1st place 2006/07: MIT

Image credit: http://web.mit.edu/aeroastro/news/design-build-flywinners.html

The AIAA DBF competition

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Specification: for 2008/09

Payload (multi-payload and multi-mission)

The air vehicle must be able to accommodate two alternate payloads:
#1 One centerline store: 4 litre bottle of water (simulated fuel tank)
#2 Two wing stores on each side of 1.5 lb each (simulated rockets)

Other requirements

- The complete system (airframe, payload and support equipment) must be stowed within two 2 ft x 2 ft x 4 ft boxes
- Takeoff distance (100 ft)
- Batteries (NiCad or NiMH; maximum weight of 3 lb)
- Limit on current draw (40 Amp fuse).
- Structural verification (lifted at each wing tip, i.e. roughly a 2.5g load case)
- Safety (inspection undertaken)
- Team makeup & eligibility of r/c pilot

The AIAA DBF competition

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- **Specification: previous years**
  - **Payload: 2007/08**

    #1 Fourteen ½ litre bottles of 1/2 lb each (simulated passengers)
    #2 Four weighted blocks (simulated cargo)

  - **Payload: 2006/07 (reported at Samara)**

    #1 Air sampler system (speed mission)
    #2 Camera ball system (endurance mission)

The AIAA DBF competition

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Specification: changes each year

Year	Payload	Battery Wt (lb)	Field Length (ft)	Mission/Restrictions
1996/97	Steel, 7.5 lb	2.5	300	Maximum number of Laps
1997/98	Steel, 7.5 lb	2.5	300	Added landing credit
1998/99	Water	none	100	Change payload each lap, 9 ft wingspan limit
1999/2000	Water	5.0	100	Multi-mission Cargo/ferry format, 7 ft wingspan limit, added RAC
2000/01	Steel / tennis balls	5.0	200	Multi-cargo format, 10 ft wingspan limit, RAC
2001/02	Softballs	5.0	200	Multi-mission Position/Passenger Delivery/Return, Timed mission, RAC
2002/03	6"x6"x12" Box, 5 lb	5.0	120*	A/C must disassemble to fit in box, multi-mission Decoy/ Deployment/ Repeater, timed mission, RAC
2003/04	Water	5.0	150	Multi-mission fire bomber/ferry, box disassembly, timed mission, RAC
2004/05	12"x3"dia PVC, 3lb	3.0	150	Multi-mission Sensor Reposition/ Max Utilization/ Re-supply, box disassembly, timed, RAC
2005/06	Variable**	3.0	100	Multi-mission Cargo Flexibility/ Minimum RAC/ Incremental Payload, box disassembly, timed, New RAC

*Distance selected to honor the 100th anniversary of powered flight
**12"x4"x4" 5lb wood block, 48 loose tennis balls, 2x2liter pop bottles

Ref: Bovais, *et al.* (2006).

The AIAA DBF competition

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Scoring: 2008/09

- The AIAA score is computed as follows:

  SCORE = Written Report Score X Total Flight Score

- At UL, we used a different scoring:

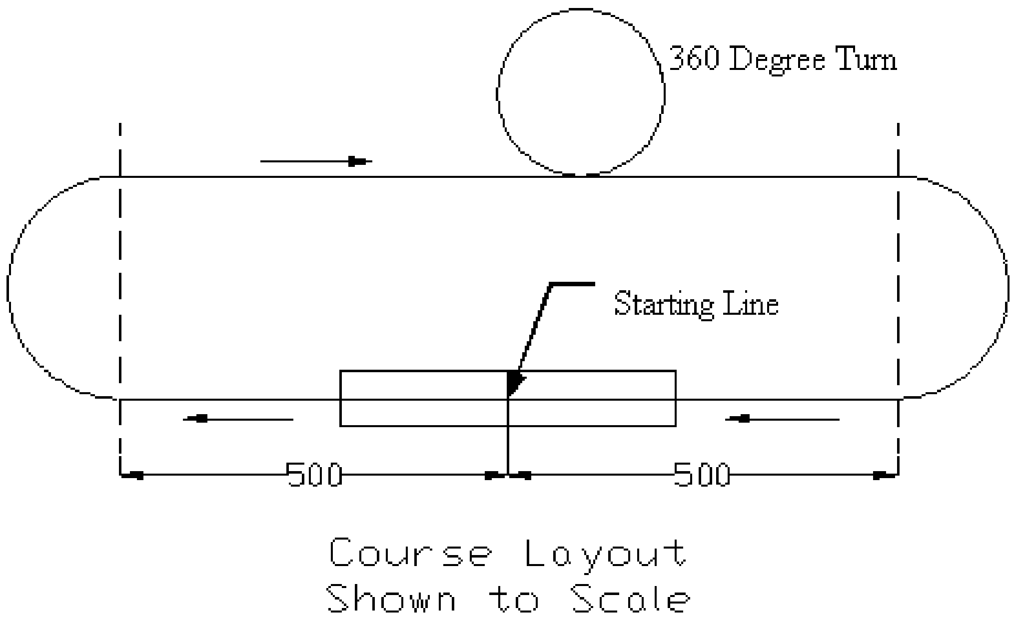
  SCORE = Written Report (50) + Construction (25) + Flight test (25)

Fig. Assessing the construction

The AIAA DBF competition

- **Scoring: 2008/09**
  - The AIAA score is computed as follows:

SCORE = Written Report Score X Total Flight Score



Includes total system weight as a metric

The AIAA DBF competition

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Scoring: previous years

- The score was computed as follows:

$$\text{SCORE} = \frac{\text{Written Report Score} \times \text{Total Flight Score}}{\text{Rated Aircraft Cost}}$$

Rated Aircraft Cost = *f* (weight, span)

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DBF at UL

B.Eng. Aeronautical Engineering at UL

- 4 year professionally accredited academic programme
- Typical class size: 30

Capstone aircraft design module

- First semester, year 4
- Typical 6 credit module
- About 22 hrs of lectures, with 22 hrs of tutorials/laboraties (11 weeks),
- Project work (prior to 2006, this was a “paper” project)

DBF

- Since September 2006 we have adopted the AIAA DBF specification
- But with a modified scoring system
- And, we did not participate in the US (not yet, anyway)

DBF at University of Limerick

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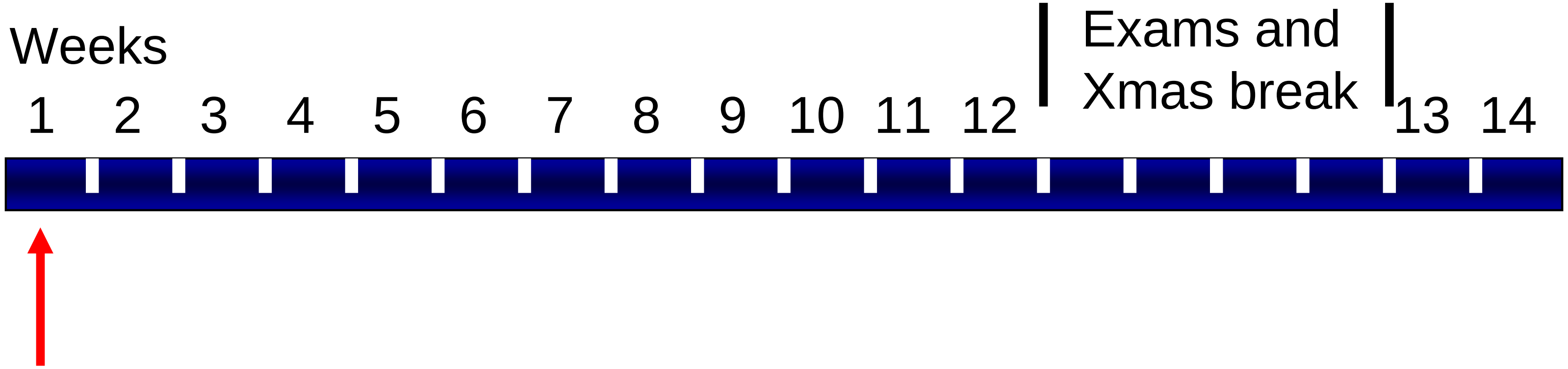
DBF at UL: Timeline



Week 1

- Announce teams: 2 or 3 teams (allocated by lecturer) of 10-14 members
- Issues specification
- Outline facilities available & contraints (e.g. budget of €1500 per team)
- Students elect team leader

DBF at University of Limerick

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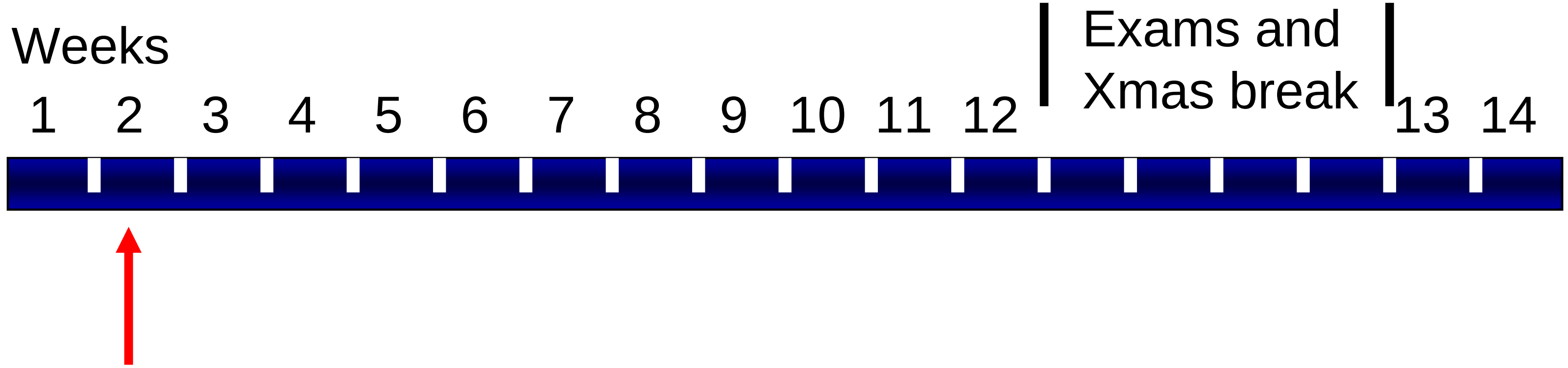
DBF at UL: Timeline



Week 2

- Students allocate responsibilities (e.g. for powerplant & batteries, aerodymanics, controls, payload, mass & balance, undercarriage, purchasing, etc.)
- Conduct requirements analysis
- Conduct literature search (previous DBF reports, papers etc.)
- Produce concept sketches
- Technical staff makes payload and containers (if needed)

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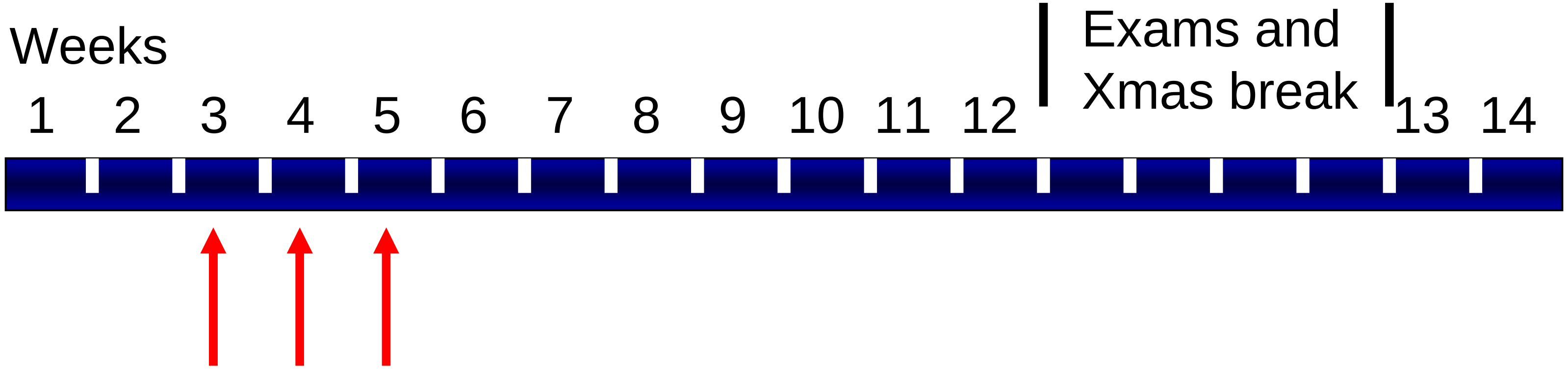
DBF at UL: Timeline



Weeks 3-5

- Preliminary design
- Weekly design reviews (attended by 2-4 members of staff, external experts or experienced postgraduate students)

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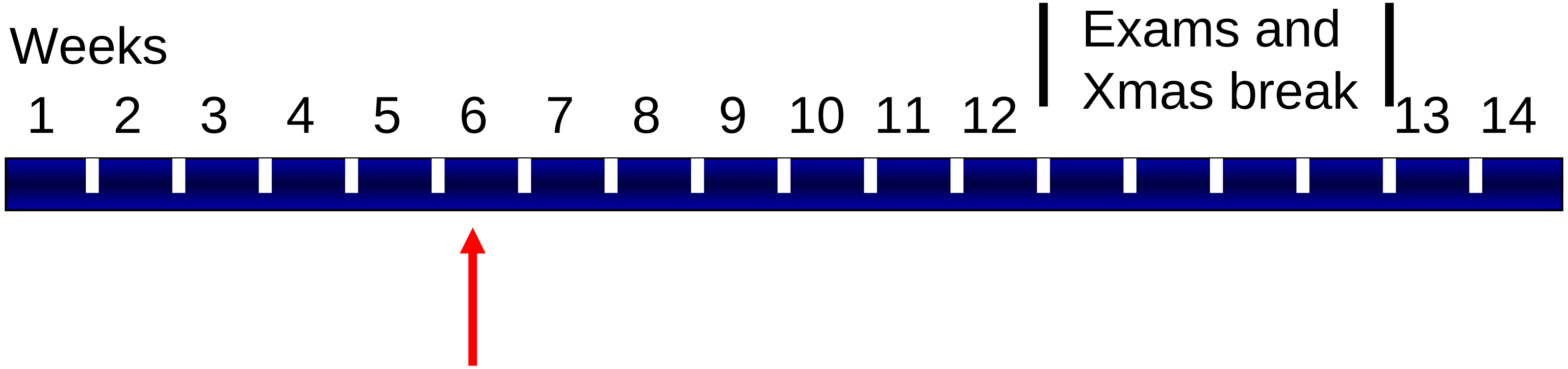
DBF at UL: Timeline



Week 6

- Interim review
- Specify motor (long lead item)
- Preliminary bill or materials (e.g. carbon fibre tubes, foam blocks)
- Initial mass & balance
- Check critical items: tail volumes, undercarriage position

DBF at University of Limerick

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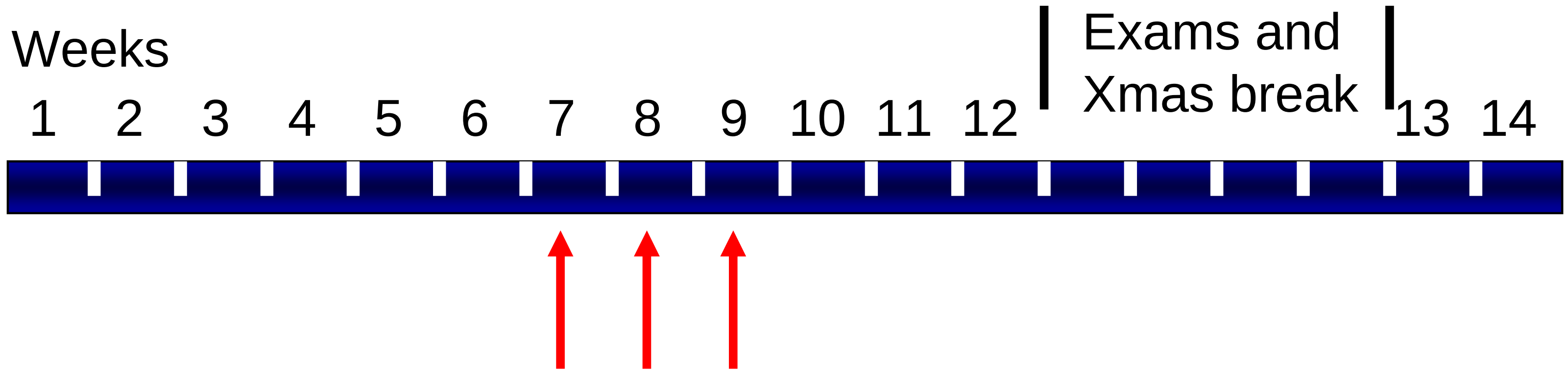
DBF at UL: Timeline

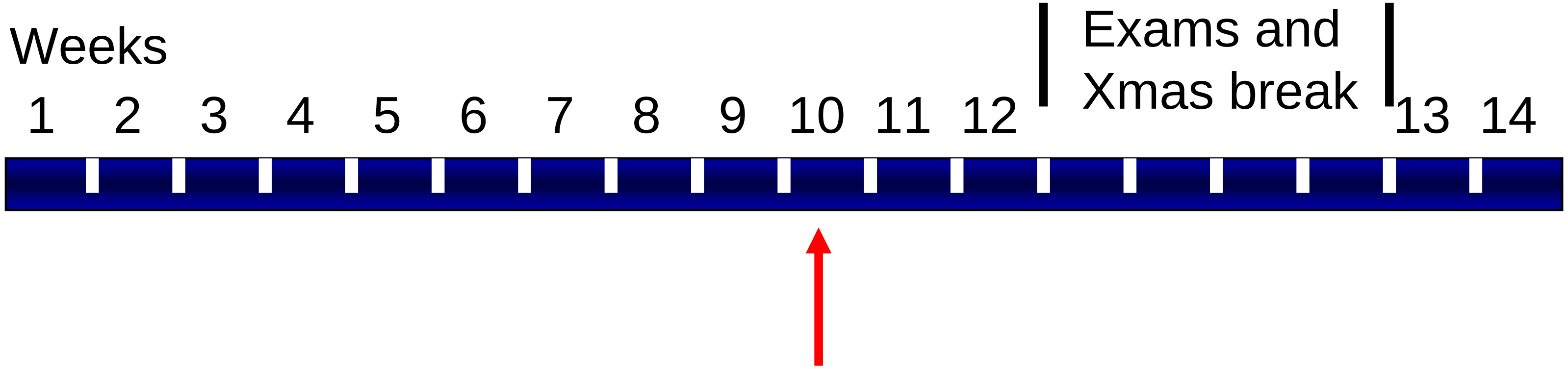


Weeks 7-9

- Detail design (update mass & balance each week)
- Purchasing (maintain running estimate of costs)
- Weekly design reviews
- Guest speakers (e.g. experienced model builder)

DBF at University of Limerick

DBF at UL: Timeline



Week 10

- Freeze design (well, try to freeze the design – these are student projects!)
- Start build

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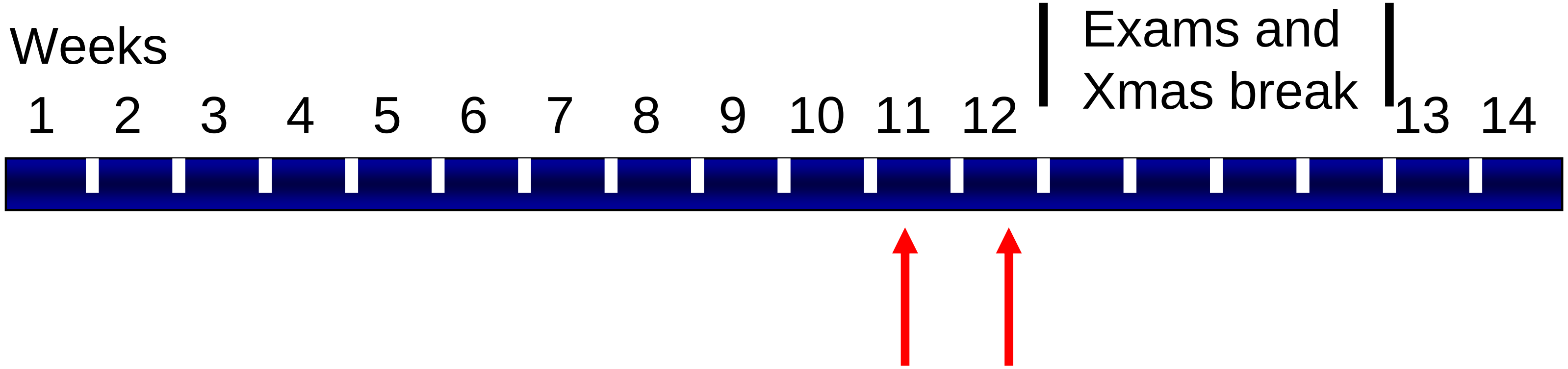
DBF at UL: Timeline



Weeks 11-12

- Manufacture sub-assemblies
- Write report

Fig. Manufacture sub-assemblies

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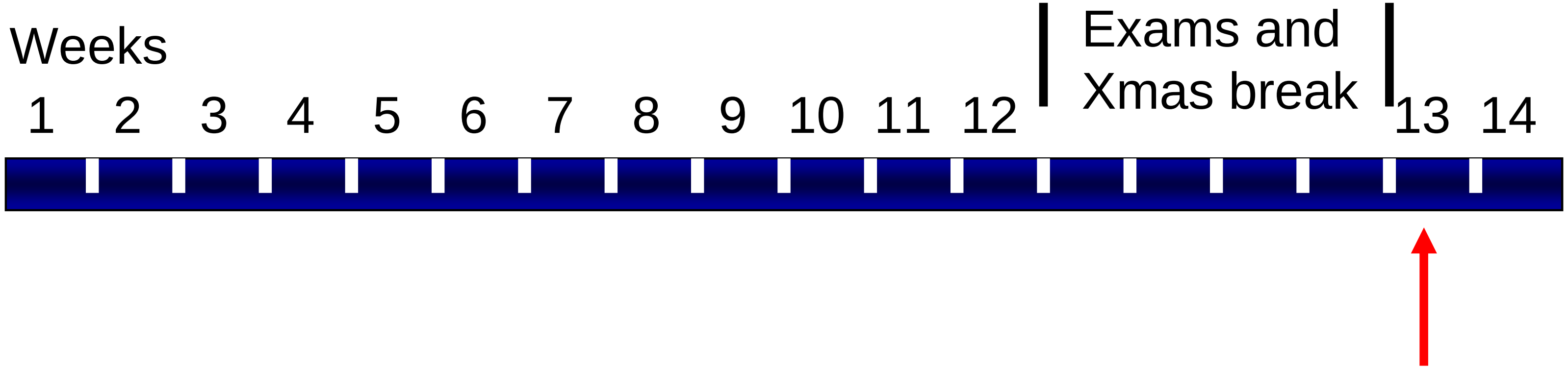
DBF at UL: Timeline



Week 13

- Final assembly

Fig. Final assembly

DBF at University of Limerick

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DBF at UL: Timeline

Weeks

1 2 3 4 5 6 7 8 9 10 11 12 | Exams and Xmas break | 13 14

Week 14

- Pre-flight evaluation: MTOW, c.g., structural integrity, safety (fuse), engine run, flight controls

Fig. Static load test (approx. 2.5 g)

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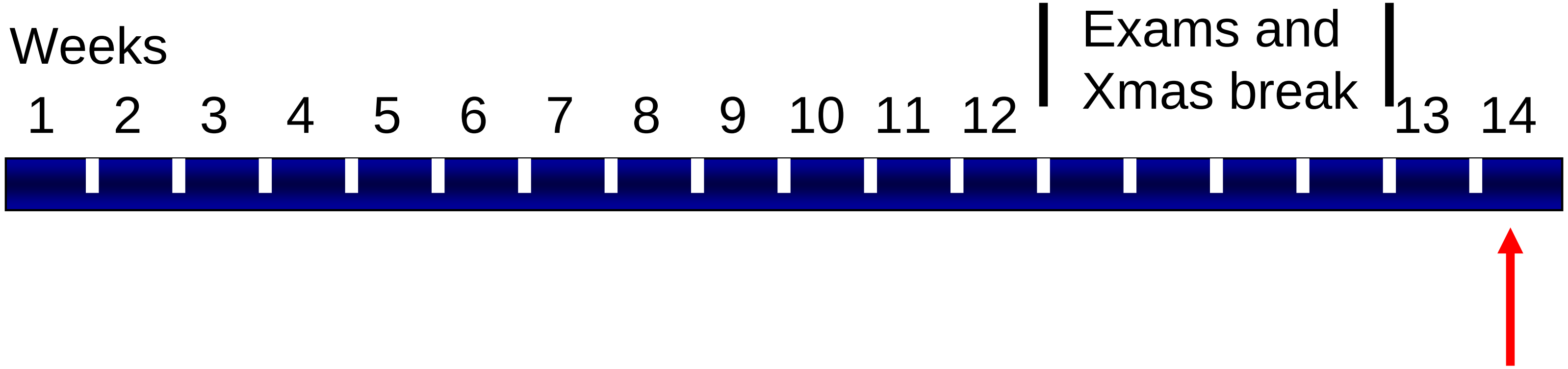
DBF at UL: Timeline



Week 14

- Pre-flight evaluation: MTOW, c.g., structural integrity, safety (fuse), engine run, flight controls
- Check special reqiuirements – e.g. drop stores

Fig. Store drop test

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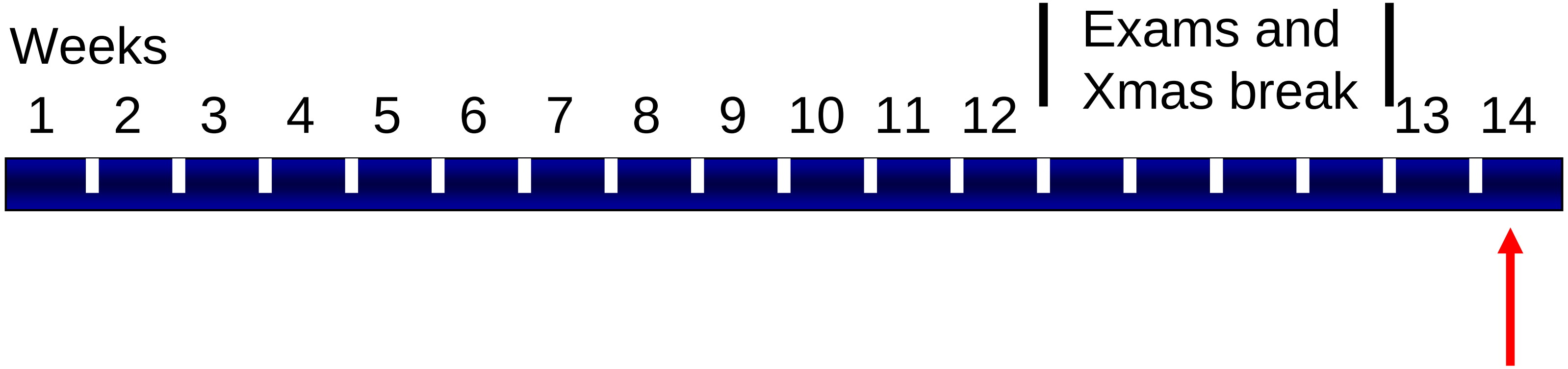
DBF at UL: Timeline



Week 14

- Pre-flight evaluation: MTOW, c.g., structural integrity, safety (fuse), engine run, flight controls
- Check special reqiuirements – e.g. drop stores
- Flight test

Fig. Flight test

Lessons learnt

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How difficult is this task?

AIAA success rate

About half of the teams fail to meet the minimum requirements for the competition (Broughton, 2006)

UL experience

Year	Teams	Observations
2006/07	3	Not one team completed the flight circuit with any payload
2007/08	2	**Team A:** completed circuit with ½ payload on first attempt **Team B:** crashed on first flight
2008/09	2	**White Team:** airborne on first attempt, but suffered flight controls problems **Green Team:** completed the circuit with full payload on first attempt

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Lessons learnt

Is it easy?

No, but that is exactly the point. It has to be an engineering challenge, not something that students can buy in a hobby shop.

Can students get academic credit for their efforts?

- Yes, it can be integrated into a standard curriculum and students can get credits. (Participating in the US competition is complicated due to the requirement to include junior students in the team.)
- Students can be graded as a team or individually.

Does the excercisehave academic value or merit?

In Samara (2007) I argued that a DBF exercise has some advantages over (a) an actual a/c design, (b) a “paper” conceptual design study, particularly for an undergraduate programme?

Lessons learnt

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Lessons learnt

Are student's enthusiastic?

I have not seen this level of enthusiasm in any other course that I have taught

Staff resources?

- Requires at least double the usual staff commitment compared to a conventional classroom module

What skills are developed?

- Technical skills
- Multidisciplinary integration
- Communication, technical drawing, report writing
- Project management
- Team work

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Lessons learnt

Time scales

- January is a terrible time of the year to test outdoors (even in Ireland)
- 14 weeks is not enough time (not when students are busy studying other subjects as well)

Changes to be introduced at UL for 2009/10

- We will test in April
- Students will have about 17 weeks for the assignment
- Report will include more engineering analysis (e.g. CFD, FEM) and test (e.g. wind tunnel tests, structural test of spar)
- Number of credits will be increased. It will be part of a new two semester module worth 12 credits).

Concluding remarks

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Concluding remarks

There are a lot of similar competitions; whis is this a good format?

- It can be integrated into a standard undergraduate curriculum.
- It is designed to be an engineering challenge.

Stated objectives (from the AIAA DBF rules)

- The contest aims to provide a real-world aircraft design experience for engineering students by giving them the opportunity to validate their analytical studies.
- The goal is a balanced design, possessing good demonstrated flight handling qualities and practical and affordable manufacturing requirements, while providing a high vehicle performance.
- To encourage innovation and maintain a fresh design challenge the design requirements and performance objectives are updated each year

A European competition?

- Several discussions have taken place regarding a European competition, to possibly start in 2010/2011.

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Trevor Young
15 May 2009

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