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AIAA’s Design, Build, Fly (DBF) Competition:
An approach to Aircraft Design Education

European Workshop on Aircraft Design Education (EWADE)
Samara: 30 May – 1 June 2007

Outline:

1. Introduction
2. The AIAA DBF rules
3. Evaluation at UL
4. The 2006/07 competition
5. Academic value and management
6. Concluding remarks
7. The next step: some options

AIAA's Design, Build, Fly (DBF) Competition:
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European Workshop on Aircraft Design Education (EWADE)
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Introduction

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- **Presentation objective**
  - Point of departure:

    The requirements for a successful academic design competition contest entry are certainly not trivial. Remote control aircraft often get overlooked as an educational tool because of their similarity to hobby airplanes. Although these aircraft may be small, they are true aircraft, and require many of the same structural, aerodynamic, and propulsion studies as full size aircraft. Furthermore, the studies must be completed by young students with limited experience on short time scales and budgets. The complexity and reality of these challenges can be a tremendous boost in a student's education, and should be included as an integral part of every engineering education program.

    Adam Broughton, "An Approach to Integration of Academic Studies with Practical Applications: Georgia Tech Design, Build, Fly", ATIO Conference, 25–27 Sep. 2006, Wichita, KS.

  - Objective for this presentation: To assess this statement.

Introduction

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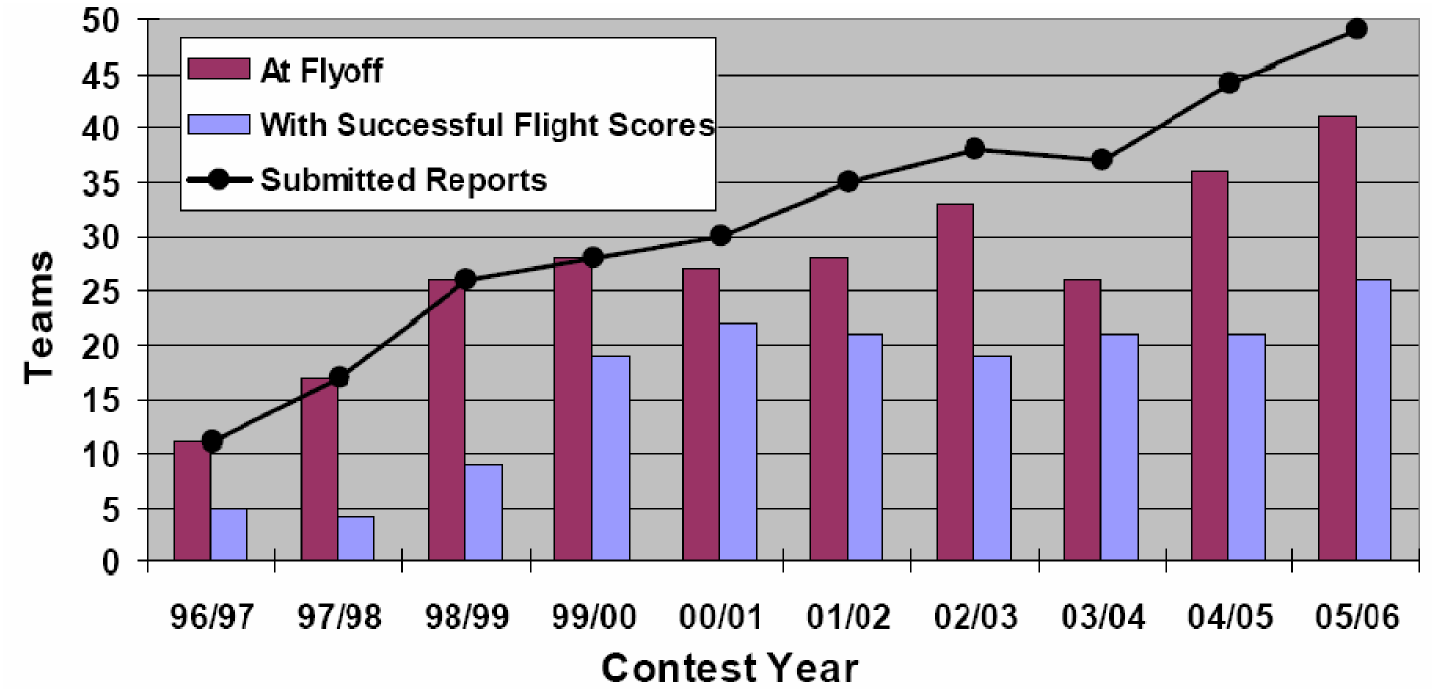
- **What is the AIAA's DBF competition?**
  - It is a student contest organized by the American Institute of Aeronautics and Astronautics (AIAA), with industry support – notably, Cessna and Raytheon Missile Systems, and formally, the Office of Naval Research (ONR).
  - Teams compete by designing, building and flying an electric, radio controlled (r/c) aircraft to meet a specification (range, endurance, payload, speed, etc.).
  - Stated goal: It is an engineering contest – not a model airplane contest.
  - The winner is determined by the best combination of
    - written report (to a specified format);
    - flight performance (determined at a competition flyoff); and
    - design (as measured by a "Rated Cost").

Introduction

AIAA's DBF competition history

Competition growth

- First DBF contest was held in 1997 (Ragged Island, MD) with 20 teams.
- Grown in popularity.



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

Introduction

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- **Stated objectives of AIAA's DBF competition**
  - The contest aims to provide a real-world aircraft design experience for engineering students by giving them the opportunity to validate their analytic studies.
  - Student teams design, fabricate and demonstrate the flight capabilities of an unmanned, electric powered, radio controlled aircraft that can best meet the specified mission profile.
  - 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. The changes will provide new design requirements and opportunities, while allowing for application of technology developed by the teams from prior years.

Ref: AIAA DBF 2007 rules (15 Sep 2006)

Specification changes

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).

Introduction

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Scoring formula evolution

Year	Scoring Formula
1996/97	Written Report * Number of Laps
1997/98	Written Report * (Laps + Landing)
1998/99	Written Report * Total Weight Carried
1999/2000	$\frac{\text{Written Report}}{\text{Rated Aircraft Cost}}\sum_{i=1}^{3}(10^{*}\#\,\text{bottles})$
2000/01	$\frac{\text{Written Report}}{\text{Rated Aircraft Cost}}\sum_{i=1}^{3}(\#\text{Heavy}+\#\text{Light}/5)$
2001/02	$\frac{\text{Written Report}}{\text{Rated Aircraft Cost}}\sum_{i=1}^{3}\frac{(\#\text{Laps}+\#\text{Balls})}{\text{Total Mission Time}}$
2002/03	$\frac{\text{Written Report}}{\text{Rated Aircraft Cost}}\sum_{i=1}^{2}\frac{\text{Difficulty Factor}^{*}}{(\text{Flight Time}+\text{Assembly Time})}$
2003/04	$\frac{\text{Written Report}}{\text{Rated Aircraft Cost}}\left[\frac{2}{\text{Time}_{\text{firefight}}}+\frac{1}{\text{Time}_{\text{ferry}}}\right]$
2004/05	$\frac{\text{Written Report}}{\text{Rated Aircraft Cost}}\left[\left[2(12-\text{Time})_{SR}+\left((\#\text{laps})\right)_{MU}+1.25(12-\text{Time})_{RS}\right]\right]^{\dagger}$
2005/06	$\frac{\text{Written Report}}{\text{Rated Aircraft Cost}}\left[\left(\frac{10^{*}\#\text{laps}}{\text{Load Time}}\right)_{CF}+\left(\frac{150}{\text{RAC}}\right)_{MR}+\left(\left(1.25\#\text{laps}^{2}\right)\right)_{IP}\right]^{\ddagger}$

* Difficulty Factors: Missile Decoy=2.0, Sensor Deployment=1.5, and Communications Repeater=1.0.
† Best two of three scores from the Sensor Reposition, Max Utilization, or Re-Supply Missions.
‡ Best two of three scores from the Cargo Flexibility, Minimum RAC, or Incremental Payload Missions.

Ref:

Bovais, *et al.* (2006).

The AIAA DBF 2006/07 rules

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- **Specifications for DBF competition 2006/07**
  - **Timetable for 2006/07 (much the same each year)**
    - Rules posted: 16 Aug 2006 (revised: 15 Sep. 2006)
    - Entry deadline: 31 Oct 2006
    - Report submission: 6 March 2007.
    - Flight test: 20-22 April 2007 (Tucson)
  - **General requirements**
    - Any configuration except rotary wing or lighter-than-air craft is permitted.
    - The complete system (airframe and both payloads) must be stowed within a maximum 2 ft x 4 ft x 1.5 ft inside dimension container.

The AIAA DBF 2006/07 rules

- **Specifications for DBF competition 2006/07**
  - **Team**
    - Team members must be full time students at an ABET accredited University or College (excl. the pilot).
    - At least 1/3 of the team members must consist of students in their first three years of study (Freshman, Sophomores or Juniors).
    - A maximum of two teams from any one educational institution (multi-campus universities may enter more teams).
  - **Payload (multi-payload and multi-mission)**

    The air vehicle must be able to accommodate two alternate payloads:

    #1 Air sampler system (speed mission)

    #2 Camera ball system (endurance mission)

The AIAA DBF 2006/07 rules

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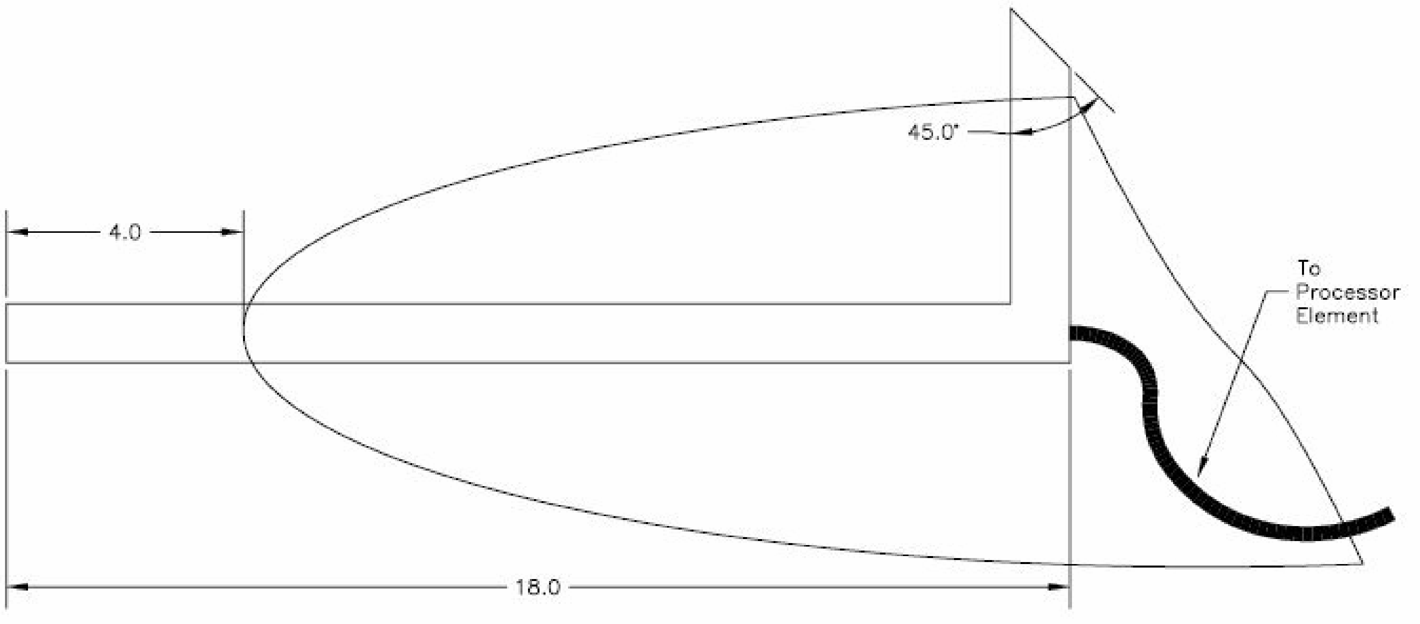
Payload #1

Air sampler system specifications

- *Sampler tube:* Plastic air sampler tube (internal diameter of 1 inch).
- *Installation:* Inlet must protrude 4 inch from the air vehicle.
- *Processor unit:* 8 inch x 8 inch x 8 inch, weighing 3 lb.
- *Connector*: 3/8 inch dia. tube connecting air sampler to processor.



The AIAA DBF 2006/07 rules

- **Payload #2**
  - **Camera ball system specifications**
    - *Camera ball:* 12 inch circumference ball
    - *Installation:* At least ½ of the ball must protrude clear of the lower surface at the lowest point of the vehicle (excluding landing gear). The ball must be behind the main landing gear (tricycle gear) or ahead of the main landing gear (tail-dragger).
    - *Processor unit:* 4 inch x 6 inch x 15 inch, weighing 5 lb.
    - *Connector:* 3/8 inch dia. tube connecting ball to processor.

The AIAA DBF 2006/07 rules

- **Key requirements**
  - **Powerplant and systems**
    - *Motors:* unmodified over-the-counter electric (brush or brushless) electric motor(s); multiple motors and/or propellers permitted; may be direct drive or with gear or belt reduction.
    - *Propellers:* commercially produced propeller and hub/pitch mechanism; no modifications to the propeller allowed (other than clipping the tip and painting the blades to balance the propeller).
    - *Power supply:* Limited to 40 Amp current draw (fused).
    - *Batteries (propulsion):* Over the counter NiCad or NiMH batteries (shrink-wrapped); maximum weight of 3 lb. Batteries may not be changed or charged between sorties.
    - *Batteries (radio and control):* Separate battery pack for radio and servos.

The AIAA DBF 2006/07 rules

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- **Key requirements**
  - **Safety inspection**
    - Physical inspection of vehicle to insure structural integrity.
    - Verify all components adequately secured.
    - Verify all fasteners tight and locked (e.g. safety wire, Locktite or nylock nuts), and flight controls have appropriate safety devices (prevent disengagement).
    - Verify propeller structural and attachment integrity.
    - Visual inspection of all electronic wiring to assure adequate wire gauges and connectors.
    - Check radio range (motor off and motor on).
    - Verify all controls move in the proper sense.
    - Check general integrity of the payload.

The AIAA DBF 2006/07 rules

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Key requirements

Safety inspection

- *Structural verification.* Aircraft will be lifted with one lift point at each wing tip to verify wing strength (with maximum payload). This is roughly equivalent to a 2.5g load case and is also a check of the cg position.
- *Radio fail-safe check.* Radios must have a fail-safe mode that is automatically selected during loss of transmit signal – sets throttle, elevator, rudder, aileron and flaps (if fitted).
- *Arming:* All aircraft must have a mechanical motor arming system separate from the onboard radio Rx switch. Crew members must not have to reach across the propeller plane to access the fuse.

Evaluation at UL

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B.Eng. Aeronautical Engineering at UL

- B.Eng. Aeronautical Engineering: 4 year professionally accredited academic programme.
- Students spend 7 months (1 summer & 1 semester) working in industry.
- Typical class size: 30
- In year 4 (first semester), students undertake a “capstone” aircraft design module.

- **Capstone aircraft design module (ME 4217)**
  - About 22 hours of lectures.
  - Students work in teams (typically 5) to design, in concept, an air vehicle to meet a given specification (RFP).
  - Each team submits a single written report, to a given format.

Evaluation at UL

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DBF evaluation

- In academic year 06/07, we adopted the AIAA DBF 06/07 specification, but not the mission specification nor the scoring system.
- No intention of participating in the US (this year).

- **Implemented as follows:**
  - *Teams:* Three teams (allocated by lecturer) of 10 members each.
  - *Budget:* €1500 per team.
  - *Time:* One semester (11 weeks).
  - *Pilot:* Experienced r/c pilot was provided (from local model flying club).
  - *Support:* Technical staff, purchasing, access to r/c pilots and know how.
  - *Meetings:* Weekly team / staff meetings

Competition 2006/07

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11th Annual AIAA DBF Competition

Summary

- Venue: Tucson, Arizona
- Dates: 20 - 22 April 2007
- Host: Raytheon Missile Systems

Cessna Aircraft Company
Raytheon Missile Systems
AIAA Foundation

Entrants

Countries	Universities	Teams
USA	45	55
Scotland	1	1
Turkey	2	2
Israel	1	1
United Arab Emirates	1	1
Totals*	**50**	**60**

* 49 teams took part (Ref: http://www.rcgroups.com/forums/showthread.php?t=678448)

Competition 2006/07

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Scoring

- The team's overall score was computed as follows:

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

Written Design Report

1. Executive Summary (5 points)
2. Management Summary (5 points)
3. Conceptual Design (20 points)
4. Preliminary Design (30 points)
5. Detail Design (15 points for discussion items, 10 points for drawings)
6. Manufacturing Plan and Processes (5 points)
7. Testing Plan (10 points)

Competition 2006/07

UNIVERSITY of LIMERICK
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Scoring

- The team's overall score was computed as follows:

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

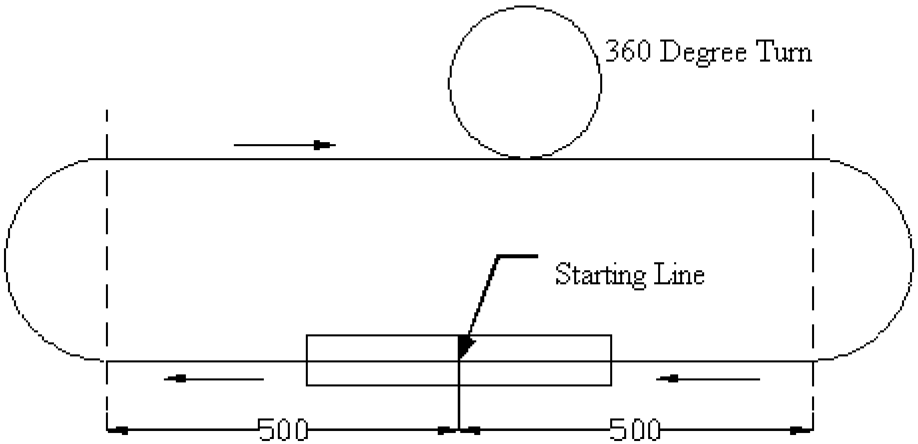
Total Flight Score

1. Sampling mission (speed)

Aircraft take-off and fly two timed laps and land. Scores are normalized based on the time of the best scoring team.

2. Surveillance mission (endurance)

Aircraft take-off and fly two timed laps and land. Each lap must be at least 2 minutes long.



Course Layout
Shown to Scale

Competition 2006/07

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Scoring

- The team's overall score was computed as follows:

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

Rated Aircraft Cost (RAC) = MEW*SPAN

Coef.	Description	Value
MEW	Manufacturers Empty Weight	Actual airframe weight [lb] with all flight and propulsion batteries but without payload.
SPAN	Wing Span	Greatest possible measurement [inches] perpendicular to the aircraft flight axis from the tip of any wing or aerodynamic surface to the tip of any other wing or aerodynamic surface.

Competition 2006/07

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- **11th Annual AIAA DBF Competition**
  - **Winners**
    1. Massachusetts Institute of Technology (MIT)
    2. Oklahoma State University (OSU) Orange team
    3. Purdue University
  - **Cash prizes**

    \$2500 for 1st, \$1500 for 2nd and \$1000 for 3rd place.

Competition 2006/07

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11th Annual AIAA DBF Competition

Fig. 1st place: MIT design: 24 inch span biplane (weighing less than 2lb)

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

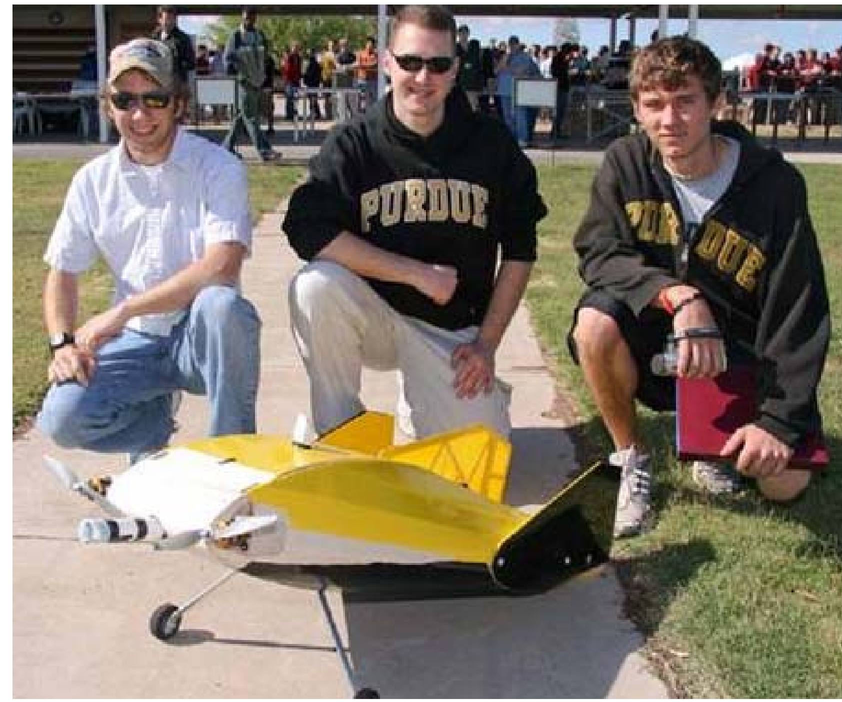

Fig. 3rd place: Purdue design: 24 inch lifting body with two counter-rotating propellers

Image credit: http://www.rcgroups.com/forums/showthread.php?t=678448

Competition 2006/07

- **Best designs in recent years**
  - Oklahoma State University – most successful university in recent years

Fig. 2004/05 OSU's B-5 Blackout (contest position: 1st)

Image credit: Arena (2006)

Fig. 2004/05 OSU's Diamondback (contest position: 2nd)

Image credit: Arena (2006)

Competition 2006/07

- **Best designs in recent years**
  - Oklahoma State University – most successful university in recent years

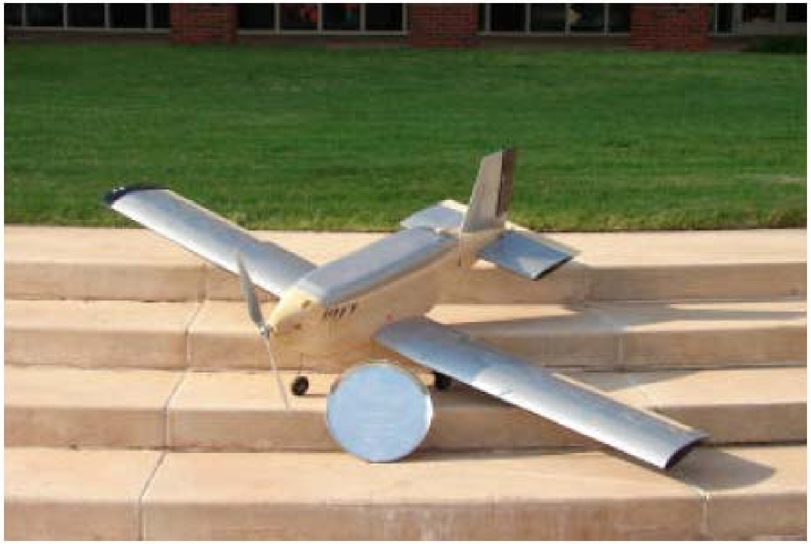

Fig. 2005/06 OSU's Black Lightening (contest position: 1st)

Image credit: Arena (2006)

Fig. 2005/06 OSU's Flying Slug (contest position: 2nd)

Image credit: Arena (2006)

Academic value and management

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- **Some questions arise?**
  - **Schedule?**

    How does this exercise fit into an academic calendar?

  - **Student grade?**

    Does this form part of the students' academic evaluation? And if so, how?

  - **Academic merit?**

    Can such a competition be regarded as having academic value? And if so, is it a better mechanism than, for example a "paper" conceptual design study?

Academic value and management

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Management

Options for implementation

	Students' work graded?	
	Yes	**No**
Mandatory for all students (i.e. core module)	√	n/a
Elective module (i.e. selected by students)	√	√
Extra-curricular activity (i.e. a student "club")	n/a	√

√ = viable option

Note: Implementation may be different for juniors.

Academic value and management

- **Comparison of approaches to teaching aircraft design**

	"Paper" design study	Actual hardware design	R/c unmanned aircraft

Students work in teams to conduct a theoretical study – usually a conceptual design of a whole air vehicle to a given specification (e.g. "Raymer" approach).

Suited to B.Eng. and M.Eng. level.

Students work indivi-dually or in teams to conduct a study of an aircraft component or system as part of the design of a new aircraft.

Suited to M.Eng. level.

Students work in teams to design, build, and test a radio controlled aircraft to a given specification.

Suited to B.Eng. and M.Eng. level.

Academic value and management

- **Comparison of approaches to teaching aircraft design**

	"Paper" design study	**Actual hardware design**	**R/c unmanned aircraft**
Cost (incurred by university)	Very low	High	Medium
Time (spent by student)	Low	High	High
Supervision (staff demand)	Easy	Complex (design specialists)	Medium
Real life specification (RFP)	Yes	Yes	No
Complete design cycle (design, build, test)	No (usually conceptual design)	Sometimes	Yes

Students never see the consequences of their designs!

Academic value and management

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Comparison of approaches to teaching aircraft design

	"Paper" design study	Actual hardware design	R/c unmanned aircraft
Cost (incurred by university)	Very low	High	Medium
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Supervision (staff demand)	Easy	Complex (design specialists)	Medium
Real life specification (RFP)	Yes	Yes	No
Complete design cycle (design, build, test)	No (usually conceptual design)	Sometimes	Yes
Whole aircraft considered	Yes	No	Yes

Samara: EWADE 2007

Academic value and management

How difficult is it to meet the AIAA's DBF task?

- **Success rate?**

  About half of the teams fail to meet the minimum requirements for the competition

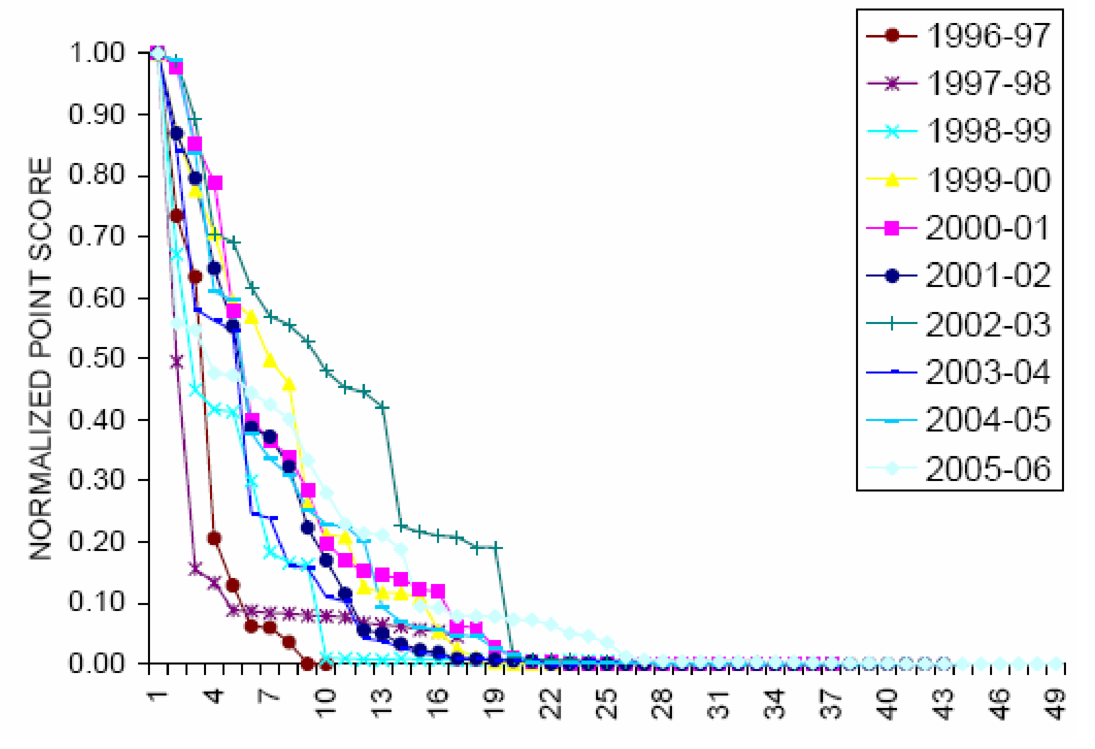

Fig. Historical success rate (Broughton, 2006)

Concluding remarks

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- **Comments on Broughton's statements (2006)**

No.	Statement (Broughton, 2006)	Comment
1	The requirements for a successful academic design competition contest entry are certainly not trivial.	Agree.
2	Remote control aircraft often get overlooked as an educational tool because of their similarity to hobby airplanes.	Agree.
3	Although these aircraft may be small, they are true aircraft, and require many of the same structural, aerodynamic, and propulsion studies as full size aircraft.	Agree.
4	Furthermore, the studies must be completed by young students with limited experience on short time scales and budgets.	Agree, it is a big challenge for students.

Concluding remarks

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- **Comments on Broughton's statements (2006)**

No.	Statement (Broughton, 2006)	Comment
5	The complexity and reality of these challenges can be a tremendous boost in a student's education,	Totally agree.
6	… and should be included as an integral part of every engineering education program.	Disagree - it is not for every university, but for many universities it could be an attractive alternative to their current approach.

The next step: some options

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- **Where to from here for those interested in such a competition?**
  - **Option 1**

    European universities interested in this contest can, either

    - use the AIAA's specification as a basis for an internal design exercise; or

    - enter the competition and attend the flyoff in the US.

  - **Option 2**

    Set up an European equivalent of this contest.

  - **Option 3**

    Approach the AIAA with a request to set up a European "chapter" managed by AIAA members in Europe (e.g. same conditions, deadlines and flyoff days).

The AIAA's Design, Build, Fly (DBF) Competition

UNIVERSITY of LIMERICK
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Dr Trevor Young
30 May to 1 June 2007

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