

CLASSIFICATION

Commercial-in-confidence Within Bird Strike GARTEUR Participants  
Minutes of GARTEUR meeting 24<sup>th</sup> & 25<sup>th</sup> May 2001

**Bird Strike GARTEUR Minutes  
of meeting held on 24<sup>th</sup> & 25<sup>th</sup> May 2001**

CLASSIFICATION

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List of attendees

Michelle Willows	QinetiQ (formerly DERA)
Lorenzo Iannucci	Imperial College of Science, Technology & Medicine
Jonathan Howes	Civil Aviation Authority
Josef Mendler	Fairchild Dornier
Fadhil Habib	BAe Systems (Warton)
Chris Bingham	BAe Systems (Warton)
Richard Budgby	Central Science Laboratory
Martin Holzapfel	DLR (Stuttgart)

Distribution

Attendees and

Eric Deletombe	ONERA
Bertrand Langrand	ONERA
Alastair Johnson	DLR (Stuttgart)
Hans Söderberg	SAAB
Paul Arendsen	NLR

## Summary

The meeting was held on the 24<sup>th</sup> and 25<sup>th</sup> May 2001 at CAA offices, Gatwick UK.

The purpose of the meeting was to present and discuss partners progress to date, check all information for the modelling round robin activities, as described in the various work packages, was complete and plan the remaining work. A significant amount of effort has been expended and, with the exception of Phase 1 Task 3, every other task within Phases 1 and 2 has been attempted by at least one partner. The work package for the bird impacts onto transparencies (Phase 1 Task 3) was tabled at the meeting and is distributed with these minutes. This completes the work package distribution.

The next meeting has been arranged for 6<sup>th</sup> and 7<sup>th</sup> December 2001 at Dornier Fairchild offices in Munich.

## Review of Actions from previous GARTEUR Meeting

Actions from previous meeting

Number	Description	Participant	Status
1	Obtain transparency impact data from SAAB	QinetiQ	Closed
2	Contact Westlands & Pilkingtons to ask for transparency data	QinetiQ	Closed
3	CSL to confirm their involvement in the GARTEUR group and return Letters of Acceptance and Adherence	CSL	Closed
4	QinetiQ to determine if reports contain sufficient data for generating a work package for Phase 1 Task 3	QinetiQ	Closed
5	QinetiQ or BAe Systems to confirm if they will be able to perform the birdstrike testing in Phase 3 Task 2	QinetiQ/ BAe	Closed
6	BAe, Dornier and DLR to check if they have any data for birdstrikes onto transparencies to form work package Phase 1 Task 3	BAe, Dornier, DLR	Closed
7	Dornier to check if they have any data for birdstrikes onto composite leading edges to form work package Phase 2 Task 2	Dornier	Closed
8	All partners to complete Phase 1 Tasks 1 and 2, and Phase 2 Task 1	All	Super-seeded
9	All partners to confirm via email that they will be able to attend the next meeting on 26th-27th April 2001	All	Closed
10	CAA to confirm next meeting arrangements	CAA	Closed

## Agenda of GARTEUR Meeting

1. Introduction
2. Review of actions from previous meeting
3. Presentations from each participant on round robin activities
4. IBRG and artificial bird development
5. Transparency data
6. AOB
7. Date of next meeting and close

## Minutes and Actions

All partners present introduced themselves and gave a brief overview of their particular interests and capabilities. Apologies were received from Bertrand Langrand and Eric Deletomb from ONERA, and Hans Söderberg from SAAB as they were unable to attend due to work commitments.

Letters of Acceptance and Adherence have now been received from all partners. Participation by CSL will be via other IBRG members who are part of the GARTEUR group.

### Work Package Distribution

Work packages for all the round robin activities in Phases 1 and 2 have now been distributed (Phase 2 Task 3 work package involving bird impacts onto transparencies has been provided by BAe Systems and is being distributed with these meeting minutes).

### Work Programme

The Work Programme was reviewed in detail and progress assessed. It was apparent that although all tasks in Phases 1 and 2 were being attempted by at least one partner, modelling work was still on-going (see Table below). Only Task 1 in Phase 1 (Rigid panel bird impacts) was complete.

	Phase 1				Phase 2		Phase 3		
	Task 1: Rigid Panel	Task 2: Metallic comp- onents	Task 3: Trans- parancies	Task 4: comp- osite panels	Task 1: sharp & blunt metallic LE's	Task 2: sharp & blunt compos- ite LE's	Task 1: Fabri- cate novel LE	Task 2: Per- Form test	Task 3: Simu- late test
DERA	Done	On-going			On-going				
Bae	Done	On-going	On-going						
DLR									
Fairchild Dornier	Done	On-going		On-going	On-going	On-going			
Imperial College	Done	On-going		Done	On-going				
ONERA	Done	On-going							
NLR									
SAAB									

The programme schedule was discussed at great length and preliminary plans made for Phase 3. Phase 1 was due to finish by September 2000 and Phase 2 by September 2001.

In the original plan (reference the Gantt Chart in the proposal) Phase 1 should have been completed (with a little overlap) prior to commencing work on Phase 2. However in practice this has not happened for various reasons. The main problem has been lack of direct funding to undertake the work so it remains of low priority and tends to be 'fitted in' wherever possible. With such external constraints the round robin activities have been somewhat fragmented. It is hoped that, although clearly not all partners will be able to undertake all tasks, at least a couple of partners will be able to simulate each task, so that collectively all tasks are modelled and some comparison of the different modelling techniques and simulation codes can be performed.

At the previous meeting a deadline for completing Phases 1 and 2 was set for October 2001 which would bring us in line with the original schedule as shown in the Gantt Chart. All partners

CLASSIFICATION

Commercial-in-confidence Within Bird Strike GARTEUR Participants  
Minutes of GARTEUR meeting 24<sup>th</sup> & 25<sup>th</sup> May 2001

present agreed that this was feasible provided the relevant work packages were made available. This deadline has been extended slightly to the date of the next meeting in December 2001. This must be achieved to allow sufficient time for Phase 3 to be completed by the end of the project in August 2002.

**Action 1: All partners to complete round robin activities in Phases 1 and 2 before the next meeting in December 2001.**

Regarding Phase 3, DLR and NLR have been tasked with fabricating a novel 'bird strike tolerant' leading edge design during Autumn 2001.

**Action 2: DLR/NLR to provide a design specification of a novel leading edge.**

**Action 3: DLR/NLR to manufacture the leading edge(s).**

Testing of the leading edge(s) will be performed by BAe Systems. Unfortunately the bird gun at QinetiQ has been dismantled and will be moved from Farnborough to Shoeburyness at some stage this year.

**Action 4: BAe Systems to confirm what test data will be generated for the FE modellers (LE deflection, video/high speed film, non-destructive evaluation, etc.)**

In addition, Dornier Fairchild may have a blunt CFRP composite leading edge available for birdstrike testing (to be confirmed in Sept/Oct '01). Impact forces and the area of delamination from non-destructive examination would be measured for comparison with the FE simulations.

**Action 5: Dornier Fairchild to confirm whether or not the composite leading edge will be manufactured and tested as part of Phase 3.**

Presentations

The presentations commenced with Fairchild Dornier giving an overview of the work package for Phase 2 Task 2 (Modelling of birdstrike onto a complex composite component). To recap a number of points were made:

TEST 1

- Ribs contained no extra ply's
- Ribs have a 'T' profile
- SFRP is a kevlar/aramid composite
- Bird impact is along Z-direction i.e. a normal impact
- Held by clamping along rear spar

TEST 2

- Ribs have a 'T' profile
- SFRP is a kevlar/aramid composite
- Bird impact is 0 degrees (includes wing sweep)
- Assume LE is simply supported and fixed in the plane of the LE skin only allowing movement along the wing

**Action 6: Fairchild Dornier to confirm various details regarding work package Phase 2 Task 2 (listed below).**

TEST 1

1. Ply lay-up of the Nose hybrid construction?
2. Dimensions for landings on ribs (T)?
3. Copy of engineering drawing of nose profile?

## CLASSIFICATION

Commercial-in-confidence Within Bird Strike GARTEUR Participants  
Minutes of GARTEUR meeting 24<sup>th</sup> & 25<sup>th</sup> May 2001

### 4. Grid distance/scale on photographs/figures?

#### TEST 2

1. Material properties for Nomex honeycomb?
2. Ply lay-up/stacking sequence, including details of any ply drops?
3. Copy of engineering drawing/section near bird impact location?
4. Grid distance/scale on photographs/figures?
5. Fails along rivet line so details of joint are required in this region for detailed modelling of rivets?

**Action 7: QinetiQ to ask DLR if the composite material data from the HICAS project could be used for modelling these structures.**

Suggested methods for modelling rivets:

- Model rivets using thin shell FE's and use tied nodes which are released when a certain stress threshold is reached.
- Use a local/global approach whereby a detailed (local) model of a small section of the rivets is first used to quantify their behaviour. This is transformed into three spring characteristics which can be used in the simplified (global) FE model to represent each rivet/bolt.
- Use a beam element between 2 nodes (with 6 degrees of freedom) within a shell FE mesh. An elastic-plastic material behaviour can be specified for the beam element.

QinetiQ presented simulation results from birdstrikes against the metallic panels at impact velocities of 93 m/s and 110 m/s (Phase 1 Task 1) using the DYNA3D code (refer to Annex 1).

Imperial College presented simulation results from birdstrikes against the metallic panels at impact velocities of 93 m/s and 110 m/s without realistic rivet modelling i.e. using tied nodes only (Phase 1 Task 1), and also preliminary simulations of a birdstrike against a blunt metallic leading edge (Phase 2 Task 1) (refer to Annex 2).

CSL outlined their participation within the GARTEUR birdstrike group which was mainly via the International Birdstrike Research Group (IBRG). The IBRG is an international consortium of aerospace companies, certification authorities and biologists, who address a wide variety of birdstrike issues from the study of flock structure to predict the probability of multiple bird ingestion to dummy bird design. Specifically CSL provides ornithological data to the group (refer to Annex 3).

Their contribution to the GARTEUR group relates to the defined bird FE model, in terms of its geometry and density. This bird model has been based on bird biometrics data collated by CSL (a copy of the report is provided with these minutes and an electronic version in PDF format is available on request).

The CAA began with a review of the certification guidelines relevant to birdstrike, namely JAR 25.631 (refer to Annex 4). Applicants are continually trying to reduce the impact velocities (relating to  $V_c$ ) which are used in birdstrike testing to attain certification. However, examination of serious birdstrike incidents (see table in Annex 4) clearly demonstrates that such 'tactics' are foolhardy and the CAA ensure that the requirements are interpreted and applied correctly. Given that there has been a substantial increase in the 'larger' bird population (e.g. the Canadian goose) strict controls are even more imperative.

A major problem that the aircraft manufacturers face is being able to perform their birdstrike testing at the correct impact velocity, partly due to the limited test facilities available and the associated costs. Often they attempt to increase the weight of the impacting bird and reduce the impact speed, thus maintaining the same impact energy. This is not acceptable as the

## CLASSIFICATION

Commercial-in-confidence Within Bird Strike GARTEUR Participants  
Minutes of GARTEUR meeting 24<sup>th</sup> & 25<sup>th</sup> May 2001

relationship between mass and velocity, in terms of the damage generated, is not linear. Indeed dynamic impact is complex and wave effects can dominate any damage produced.

Another issue that is often raised is that of 'similarity' – what constitutes a similar design? If a new design can be classified as being 'similar' to a previous design which has passed birdstrike certification testing then the manufacturer need not perform any additional birdstrike testing. Boeing are still quoting the results of their very first ditching test when requesting certification of present day aircraft, claiming that the structures are still 'similar'!

Fairchild Dornier presented simulation results of birdstrikes onto a leading edge (Phase 2 Task 2). An elastic-plastic material model was used to represent the bird and shell FE's for the leading edge with three integration points through the thickness. Reaction forces against time were compared with the test results and the peak of 70 KN compared well with the FE results.

In addition results of birdstrikes against a uni-directional CFRP composite panel (8 plies, with a symmetrical lay-up) were presented. The numerical code ABAQUS explicit was used and a new failure criteria was implemented via a user defined sub-routine to model failure of the composite material. The strain, as calculated by ABAQUS, was obtained and the stress determined. It was then checked against the new failure criteria and the stiffness of any failed FE's were set to zero, before the data was transferred back to ABAQUS for the next iteration (refer to Annex 5). The post-processor PATRAN was used to interrogate the FE results. Areas of delamination were identified using two approaches: a whole lamina approach, and a ply-by-ply approach using a user-defined integration rule.

DLR investigated two different methods for modelling the bird, namely a hydrodynamic model involving solid FE's and an SPH model. For the metallic plate impacts an elastic-plastic material model and the Johnson/Cook model were both used for the aluminium panel (refer to Annex 6).

BAe Systems presented work package Phase 1 Task 3 (Modelling of birdstrike onto a flat transparency). Three birdstrike tests were conducted onto monolithic stretched acrylic panels (refer to Annex 7). In all cases deflection curves and a description of the damage sustained were produced. Their approach to modelling birdstrike is described in Annex 8.

**Action 8: BAe Systems to provide material property data for the transparencies, and a drawing of the experimental set-up showing dimensions and clamping arrangements.**

### General Publication of GARTEUR Results

Permission for publication of all test data and corresponding numerical results relating to the work packages within Phases 1 and 2 has been granted **except** for the birdstrikes against transparencies (Phase 1 Task 3).

**Action 9: BAe Systems to confirm that the birdstrikes against transparencies data forming Phase 1 Task 3 can be published.**

Note that copies of any journal papers/material should be circulated to all members of the group for final approval prior to publication.

### Any Other Business

Other topics of interest that could form another GARTEUR group were discussed. Of particular concern was composite repair and bonded metallic repair, specifically composite patches onto composite structures and composite (non-metallic) patches onto metallic structures, e.g. carbon fibre patches onto aluminium alloys, avoiding any contact. (Boron patches have been

CLASSIFICATION

Commercial-in-confidence Within Bird Strike GARTEUR Participants  
Minutes of GARTEUR meeting 24<sup>th</sup> & 25<sup>th</sup> May 2001

certified previously). What is the possibility of repairing pressure hulls or other primary structures and still retaining certification?

Next Meeting

The next meeting has been arranged for 6<sup>th</sup> and 7<sup>th</sup> December 2001 at Dornier Fairchild offices in Munich.

**Requirements for Next Meeting from Each Partner**

- **A short report documenting the FE results from Phase 1 and Phase 2 for submission to the GARTEUR committee.**
- **A cost estimate (in £ or Euro's) of how much money has been spent on this project.**  
Please specify costs for 3 separate periods:

1/09/99 to 31/08/00 (1<sup>st</sup> year of project)

1/09/00 to 31/08/01 (2<sup>nd</sup> year of project)

1/09/01 to 30/11/01

Annex 1

QinetiQ

Annex 2  
Imperial College

Annex 3

CSL

## CLASSIFICATION

Commercial-in-confidence Within Bird Strike GARTEUR Participants  
Minutes of GARTEUR meeting 24<sup>th</sup> & 25<sup>th</sup> May 2001

The Central Science Laboratory's Birdstrike Avoidance Team (BAT) has been providing research and consultancy services on the birdstrike problem for over twenty five years. The Team provides aerodrome related advice to civil airport authorities and airforces throughout the world as well as services to the aeronautical industry.

BAT have biological skills and knowledge which compliment the skills of engineers in many aspects of birdstrike tolerance. The identification of birdstrike species is important to engineers who need to know the species and hence mass of the birds causing damage. BAT can identify birdstrike remains microscopically or using DNA techniques. BAT also review birdstrike records and ornithological data to derive operation birdstrike risk levels and possible future trends in risk.

To further enhance the link between biologists and engineers, the International Birdstrike Research Group was formed. The IBRG is a consortium of aerospace and regulatory organisations and biologists. The research programme of the group is directed by the requirements of the member organisations. Current research projects include the study of bird flock structure as a predictor of multiple bird strike probability and the measurement of bird biometrics data in order to develop a better artificial bird for birdstrike testing.

The use of artificial birds in component testing and development can ease the health and safety problems associated with real birds and can ensure that tests are standardised throughout the world. In fact, the ready availability of a standard artificial bird to all manufacturers is required by regulators before tests with artificial birds could be accepted in compliance tests. The findings of the IBRG biometrics study are included with these minutes in a report which includes all the density and dimension measurements taken from a range of commonly struck species and suggests a series of artificial bird designs based on those measurements which could be used as the basis for a standardised artificial bird. The forthcoming IBRG work programme includes the investigation of other mechanical properties of birds such as sharp edge splitting behaviour and the comparison of real birds and artificial birds in back to back impact tests. Alternatives to traditional gelatine which are safer behaviour more reliably in tests will also be investigated.

Membership of IBRG comprises: BAE Systems, Quinetic, the Gas Turbine Research Establishment - India, General Electric Aircraft Engines, Rolls-Royce PLC and the UK Civil Aviation Authority. For further information on the group, contact:

Richard Budgey  
Central Science Laboratory  
Sand Hutton  
York  
YO41 1LZ  
United Kingdom

tel. 01904 462097  
fax. 01904 462111  
[r.budgey@csl.gov.uk](mailto:r.budgey@csl.gov.uk)  
[www.csl.gov.uk](http://www.csl.gov.uk)

Annex 4

CAA

Annex 5

Fairchild Dornier

Annex 6

DLR

Annex 7

Work Package for Phase 1 Task 3

Annex 8  
BAe Systems

## GARTEUR BIRDSTRIKE WORKING GROUP TO APRIL 2001

BAe Systems has available to it the codes LS-DYNA and LL-DYNA for performing birdstrike analyses. The aim is to develop analytical methods and confidence in these methods so as to reduce the reliance on testing in the design process.

BAe Systems performed initial analyses on the metallic flat plate structure using two methods. An equation of state based bird model and a bird model with a plastic failure strain criteria. The two Dyna codes produced very similar results for these tests.

The equation of state bird model has been used with some success for glancing incidence events however the performance on the flat plate normal incidence was not considered to be acceptable. The mesh under the impact location expands as the contact progresses and it was considered that whilst the average pressure and total load transfer might be acceptable the load distribution was poor. The load in the target was shown to be concentrated under the bird nodes and this is a potential cause of premature failure of the target. This effect was shown to be less significant (but still present) when a surface-surface contact interface was used as opposed to a node-surface contact interface. However the node-surface approach was found to be necessary when penetration was present otherwise the analysis worked incorrectly. This is believed to be due to the code's difficulty in determining element normals under penetration.

The plastic failure strain model was shown to be more sensitive to the value of failure strain than would have been liked and required a very fine mesh bird and hence high CPU times to produce any reasonable results.

On the basis of these disappointing results a decision was made to investigate other approaches to Bird modelling to overcome or reduce the mesh dependency of the Lagrangian approaches.

Two methods were looked at, the SPH (Smooth Particle Hydrodynamic) method in AUTODYN and the Coupled-Euler approach in LS-DYNA.

AUTODYN was only available to BAe Systems on a short term basis but the SPH method looked promising as a method of representing the bird. Interestingly this technique is under development for potential future incorporation into LS-DYNA.

The Coupled-Euler approach in LS-DYNA has been investigated and reported to the GARTEUR group at the October 2000 meeting. The results of this looked promising but it requires further development. As yet it has not been applied to the GARTEUR tasks.

As a further contribution to the working group BAe Systems have agreed to provide some transparency test panel data and perform some testing on a composite leading edge.

Expenditure to date:-

09/1999 – 08/2000 58500 euros

09/2000 – 08/2001 58500 euros