TOWARDS STANDARDISED BIRDSTRIKE RESISTANCE TESTING: THE WORK OF THE INTERNATIONAL BIRDSTRIKE RESEARCH GROUP

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SUMMARY

- The formation of the CSL Birdstrike Research Club was described at the Vienna meeting of BSCE
- The group has changed its name to the International Birdstrike Research Group to better reflect its constituent parts and research objectives
- The main thrust of the work continues to be gathering of data to establish representative world-wide standards for birdstrike resistance testing
- To this end, work has continued on the measurement of whole body density and biometrics of species hazardous to aircraft
- Data on the internal organ density and development of 3-d computer reconstructions has also been carried out
- Stereo imaging of flocks to determine individual bird separations is also in progress
- These data are being used for computer modelling of birdstrike events in order to calculate the probability of particular numbers of a given species being hit
- The group has also produced guidelines for airport developers and planners for the reduction of the attractive features to birds in airport designs

Key Words: Engineering, Engines, Certification Standard, Civil Aviation, Flock Density, Testing, Substitute Birds

1. INTRODUCTION

At the 22nd. meeting of Birdstrike Committee Europe in Vienna, I reported the formation of the Central Science Laboratory Birdstrike Research Club, which was established to conduct collaboratively funded research into the birdstrike hazard (Allan 1994). In order to better reflect both its membership and objectives, the group has since changed its name to the International Birdstrike Research Group (IBRG). This paper reports on the work conducted by the IBRG in the past two years.

The majority of the research carried out has been with regard to the need to develop realistic standards for birdstrike resistance testing, particularly in relation to the development of dummy birds. This work falls into three main areas; the measurement of the physical properties of whole bird bodies, the measurement of internal organ density and body structure, and the measurement of the separation of birds in flocks. To the latter we have added the modelling of birdstrike events using flock structure data already obtained. Most of the methods employed were described in 1994 and will not be repeated here.

Membership of the IBRG continues to grow. Current members are Rolls Royce, UK Civil Aviation Authority, General Electric, British Aerospace, US Air Force Wright Laboratory and Pratt & Whitney. The project continues to be endorsed by both the US Federal Aviation Administration and the Joint Aviation Authorities of the European Union.

2. PROGRESS TO DATE

2.1 Physical properties of whole bird bodies:

Work has continued on gathering data on European bird species to compliment that obtained in North America (Seamans et al. 1995). Whole body density data have been gathered on a total of 22 bird species using the volumetric tubes described by Seamans et al. (1995). In addition, for European species, data have been gathered on the proportion of the total mass contained in the extremities of the body (i.e. the legs, wings, head and neck) and on the dimensions of the torso once the extremities are removed. These data will allow calculations of the length/diameter ratio of the torso to be made and the proportion of the total mass present in the torso to be determined. This information is needed if a standardised dummy bird is to be developed which is representative of the birds normally struck in operation. It also allows a more accurate estimation of the force per unit area exerted during a birdstrike to be made.

A sample set of data for Black-headed Gull (*Larus ridibundus*) is given below.

Table 1(a) whole body density (mean and std. deviation)

Feathered Density g/cc	Plucked Density g/cc
0.638 (0.036)	0.996 (0.078)

Table 1(b) distribution of mass (mean and std. deviation)

Total Mass g	Mass Of Extremities g	Mass Of Torso
305.32 (36.85)	108.6 (6.2)	196.72 (10.24)

Table 1 (c) physical dimensions

Total Length mm	Length Of Torso mm	Diameter mm	Length / diameter ratio of whole bird	Length / diameter ratio of torso only
376.2 (15.64)	75 (4.1)	64.6 (3.2)	5.99 (2.4)	1.16 (2.2)

In the case of the Black-headed Gull (above) if a real bird were used in a test some 36% of the total mass would be acting through the head, neck, legs and wings which move in an unpredictable manner. The whole body, including tail feathers has a length/diameter ratio of 5.99. The plucked torso, however, carries 64% of the mass in a compact, tapering cylinder, with a length/diameter ratio of 1.16. Should dummy birds be designed to mimic the properties of a bird's torso, or the whole bird? Should their densities represent feathered or plucked birds? These data will help to provide the information needed to answer to these and other questions as the industry moves towards a standard dummy bird for engine testing.

2.2 Organ density and internal structure

Measurements of the density of the different organs and tissues of 20 European and North American species have now been made. Table 2 shows organ density data for North American Herring Gull (*Larus argentatus*).

Table 2 density of the various organs of a Herring Gull

ORGAN	SKIN	LEG MUSCLE	BREAST MUSCLE	HEART	LIVER	GIZZARD	INTESTINE	TRACHEA	LUNG
DENSITY G/CC	0.975	1.158	1.064	1.041	1.098	1.075	1.051	0.364	0.823
ORGAN	KIDNEY	THIGH	FEMUR	HEAD	CORACOID	KEEL OF STERNUM	SPINE	PELVIS	HUMOURS
DENSITY G/CC	1.048	0.968	1.025	0.895	1.353	0.902	1.143	1.031	1.303

These data can be used in the modelling of engine fan blade impacts with birds (Allan 1994), and may also be incorporated in finite element models of birdstrikes. In order to achieve this, the internal arrangement of the different organs needs to be determined accurately in three dimensions. At present this is achieved by slicing the frozen body of the bird and reconstructing a computer model using digitised images of the slices obtained (Allan 1994). Work is currently underway to adapt Magnetic Resonance Imager (MRI) or Computer Aided Tomography (CAT) data for this purpose. This work is being conducted in collaboration with IBRG by the USAF's Wright Patterson Laboratory, and is to be reported on elsewhere in this conference (Short & Seamans WP 65).

2.3 Flock structure and modelling of birdstrike events

Gathering of data on the individual spacing if birds in moving flocks is continuing using the stereo video monitoring equipment described by Allan (1994). A set of sample data giving instantaneous X,Y and Z co-ordinates and inter-bird distances for a small flock of Black-headed Gulls is given in table 3. Once a comprehensive database has been built up, it will be possible to determine what environmental and behavioural factors influence flock structure, which may have applications in the study of bird behaviour and bird control on airfields.

As well as answering basic questions about flock structure, these data are being used to model birdstrike events. A three dimensional computer simulation, which allows aircraft, engines or other components to be passed through a bird flock in a variety of directions, angles of climb etc. has been developed. The model can be run repeatedly and many thousands of birdstrikes simulated with each flock. A probability distribution of the number of strikes on various parts of the aircraft can thus be developed, and the likelihood of, for example, and ingestion involving two birds entering an engine determined for that flock. Once a reasonably large number of flocks have been modelled, the results obtained can be

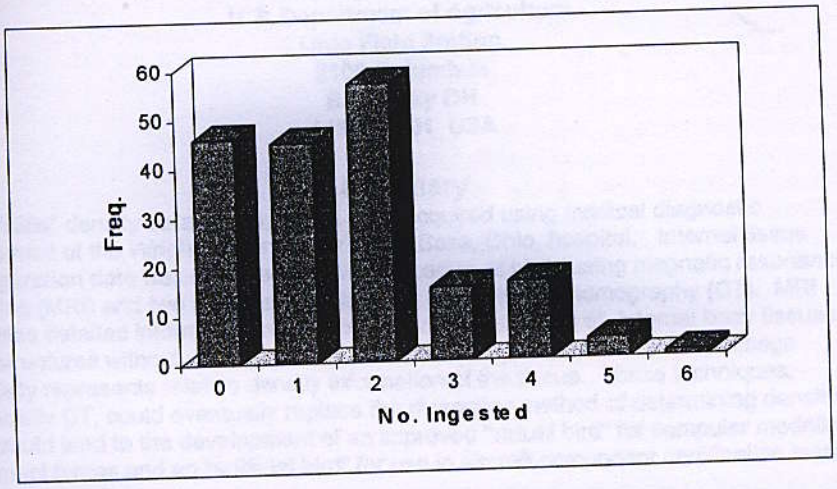
Table 3 example of coordinates and inter bird distances for a flock of Black-headed Gulls

Normalised Coordinates (m)				Inter Bird Distances (m)													
X	Y	Z		Bird 1	Bird 2	Bird 3	Bird 4	Bird 5	Bird 6	Bird 7	Bird 8	Bird 9	Bird 10	Bird 11	Bird 12	Bird 13	Bird 14
0.00	2.29	6.56	Bird 1	a	0.70	1.43	18.43	3.32	8.39	10.39	6.75	3.78	10.46	6.50	5.60	15.82	6.31
0.07	2.78	6.07	Bird 2	0.70	a	0.91	18.95	3.77	8.86	10.83	6.22	4.19	10.97	6.34	5.61	16.26	6.47
0.52	2.69	5.29	Bird 3	1.43	0.91	a	19.73	4.48	9.61	11.61	5.37	4.20	11.59	5.57	5.39	16.73	6.36
0.05	1.52	24.98	Bird 4	18.43	18.95	19.73	a	15.29	10.21	8.36	25.06	17.75	9.09	22.78	18.64	9.29	17.78
0.88	2.61	9.75	Bird 5	3.32	3.77	4.48	15.29	a	5.13	7.18	9.77	3.95	7.24	8.38	5.33	12.72	5.48
1.05	2.66	14.88	Bird 6	8.39	8.86	9.61	10.21	5.13	a	2.23	14.89	8.03	3.06	12.93	8.90	8.90	8.38
0.48	3.51	16.87	Bird 7	10.39	10.83	11.61	8.36	7.18	2.23	a	16.90	10.26	3.63	15.12	10.95	8.64	10.45
1.43	3.51	0.00	Bird 8	6.75	6.22	5.37	25.06	9.77	14.89	16.90	a	8.21	16.65	5.14	8.32	21.30	9.55
2.84	0.00	7.52	Bird 9	3.78	4.19	4.20	17.75	3.95	8.03	10.26	8.21	a	9.01	5.21	3.76	13.61	3.59
3.18	1.11	16.45	Bird 10	10.46	10.97	11.59	9.09	7.24	3.06	3.63	16.65	9.01	a	13.83	9.66	6.03	8.71
4.91	0.38	2.75	Bird 11	6.50	6.34	5.57	22.78	8.38	12.93	15.12	5.14	5.21	13.83	a	5.01	17.65	5.71
5.56	2.58	7.21	Bird 12	5.60	5.61	5.39	18.64	5.33	8.90	10.95	8.32	3.76	9.66	5.01	a	13.30	1.57
7.92	0.56	20.14	Bird 13	15.82	16.26	16.73	9.29	12.72	8.90	8.64	21.30	13.61	6.03	17.65	13.30	a	12.09
6.03	1.49	8.24	Bird 14	6.31	6.47	6.36	17.78	5.48	8.38	10.45	9.55	3.59	8.71	5.71	1.57	12.09	a
			Nearest Neighbour Distance (m)	0.70	0.70	0.91	8.36	3.32	2.23	2.23	5.14	3.59	3.06	5.01	1.57	6.03	1.57
			Furthest Neighbour Distance (m)	18.43	18.95	19.73	25.06	15.29	14.89	16.90	25.06	17.75	16.65	22.78	18.64	21.30	17.78

used to validate current certification requirements or to help develop new test standards as new engines and aircraft are developed.

Fig. 1 shows a sample set of data for a modelled passage of a single jet engine with a 100 inch fan diameter through a flock of 20 Lapwings (*Vanellus vanellus*) filmed as they moved from one feeding site to another, as they would on an airfield. The model was run for a total of 184 passes through the flock from angles between -11 degrees to +5 degrees to the horizontal. The data show that, for this flock, the number of birds most frequently ingested is two, with the largest number, 6, being encountered on only one occasion in the 184 passes. This model gives a 'worst case' estimate of the true situation, because, in this simple example, engine always passes through the geometric centre of the flock. The model is designed to allow the engine to pass through the periphery of the flock, which would increase the frequency of low numbers of birds being ingested. It is interesting to note that a large fan engine can pass through the centre of this flock of birds and, purely by chance, fail to hit anything on 24% of occasions.

Figure 1 Results from a simulated birdstrike using real flock structure data: The numbers of Lapwings from a flock of 20 birds ingested into a 100 inch jet engine passing through the centre of the flock at varying angles.



3. SUMMARY

The IBRG has continued to gather data of great importance to the aviation industry over the past two years. The collaborative funding base, involving a number of potentially competing organisations, is somewhat unusual and reflects the importance attached by the members to the data being collected. The development of unique systems for data gathering and computer modelling of birdstrikes puts the IBRG is a position to provide the data that will influence birdstrike resistance testing and certification requirements for many years to come.

As well as designing and testing for resistance to birdstrikes, the IBRG membership are keen to initiate work on birdstrike prevention. The group has recently developed a set of guidelines for airport developers and planners. These guidelines were based on the Birdstrike Avoidance Team's experience in design consultancy and safeguarding of aerodromes, and will assist in eliminating features that attract birds to airports at the design stage. These will be reported elsewhere in due course.

The group would welcome suggestions for collaborative projects and would especially value participation in the group by organisations involved in birdstrike prevention.

4. REFERENCES

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