First Frederik J. Plantema Memorial Lecture

THE INTERNATIONAL COMMITTEE ON AERONAUTICAL FATIGUE (ICAF) ITS FOUNDATION, GROWTH AND TODAY'S PHILOSOPHY

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FOLLOWING a proposal from Mr J. Y. Mann of the Aeronautical Research Laboratories, Australia, my colleagues of the International Committee on Aeronautical Fatigue (ICAF) entrusted me to give the first lecture in memory of Frederik J. Plantema. It is an honour and privilege to represent the Committee, but I fear that my colleagues overestimated my faculties. It is hardly possible for a designer, who met Plantema only at the fatigue conferences, to do justice to this great scientist and researcher.

This is why I had to have recourse to the good services of my colleagues, who willingly gave me their assistance. Therefore, my address is not only on behalf of my colleagues, but also to a large extent based on their communications.

Dr J. Schijve, Plantema's successor as head of the Structures and Materials Department in the National Lucht- en Ruimtevaartlaboratorium (NLR), gave me the following record.

Dr Plantema's course of life and his contribution to aeronautical research

Frederik J. Plantema was born on 21 October 1911 at Leeuwarden in The Netherlands. He graduated from the Technological University of Delft at the age of 21 years. For a short period he was assistant to Professor Biezeno at the same university, and in 1934 he joined the National Luchtvaartlaboratorium (NLL) in Amsterdam. In 1945 he was charged with the leadership of the Structures Department and in 1950, when the Structures Department and the Materials Department became one joint department, he was appointed to be the head of it, which he remained until his death.

In 1952 he obtained his degree of Doctor of Technical Sciences, the title of the thesis being *Theory and experiments on the overall instability of flat sandwich plates.*

Dr Plantema was a member of the Structures and Materials Panel of the Advisory Group for Aeronautical Research and Development (AGARD) and of the Fatigue Committee of the same Panel. He was also a member of the Netherlands Committee on Structural Strength Requirements for Civil Aircraft, and an Associate Fellow of the Institute of the Aeronautical Sciences. In April 1966 he was royally distinguished as Officer of the Order of 'Oranje Nassau'.

When Dr Plantema joined the NLL the epoch of the all-metal civil aircraft had just begun, and he was immediately involved in the development of new methods for stress analysis of the new types of structures. At the same time he had to study the rationalization of airworthiness requirements and hence he was frequently engaged in problems related to external loads on aeroplanes. Due to the increasing utilization of aircraft and the use of high strength aluminium alloys Dr Plantema had to consider not only aircraft fatigue loads but also the consequences of these loads for aircraft structures.

He wrote a large number of papers and reports on a large variety of subjects such as: torsion of aircraft structures, allowable stresses in thin-walled cylinders, loads on tricycle landing gears, buckling of flat and slightly curved plates, loads on wings and tailplanes due to displacements of rudders or flaps, stress distribution in shells, rationalization of gust load requirements, rolling-manoeuvre loads on aeroplanes, fatigue of structures and structural components, flexibility effects of aircraft during landing, fatigue tests on stiffened panels, strength testing of aeroplanes, buckling of struts, cumulative damage, fatigue tests on sandwich panels, airworthiness requirements for pitching manoeuvres, experimental investigations on runway waviness and bending of orthotropic plates under transverse loading. He wrote a book in Dutch on the stress analysis of aircraft structures. In 1966, shortly before his death, his book *Sandwich Construction* was published by John Wiley and Sons. This is a more or less random list of subjects drawn from a collection of his publications. Several papers were contributed to international conferences and symposia, and to well-known technical journals. All his publications were characterized by a lucid style, a clear description and analysis of the problem, and a careful formulation of the conclusions.

Although he was not very frequently engaged in fatigue experiments he stimulated fatigue research and gave advice throughout his career, and he had the responsibility for all of the fatigue work carried out at his department by his co-workers. All drafts of fatigue reports passed through his hands and

often they were considerably improved by his alert criticisms. Due to his broad field of activities he was capable of reducing 'conclusions' to their proper significance.

Of direct importance for the members of the International Committee on Aeronautical Fatigue is the part which Plantema played in this Committee, because above all it is he to whom belongs the merit of this Organization.

The formation and the evolution of ICAF

In 1949 Plantema completed an analytical study entitled: *Fatigue of Structures and Structural Components.** In the conclusions of this study he said that it would be necessary to consult laboratories in other countries to see whether his recommendations for fatigue research were in agreement with test programs going on elsewhere, and that this could lead to a useful international exchange of results. Here the idea of ICAF was born.

In 1951 the initiative for the foundation of ICAF was taken by F. J. Plantema. At that time he was head of the Structures Department of the NLL and in this function he was faced with the problem of aircraft fatigue. He wrote letters (dated 11 May 1951 and signed by the late director Koning) to the College of Aeronautics (CoA), Cranfield and to the director of the Flygtekniska Försöksanstalten (FFA) in Stockholm. In these letters Plantema proposed to come to a close co-operation between various institutes. The co-operation was to consist of an exchange of reports and other information at the earliest possible date and the establishment of common research programs to avoid unnecessary duplication. He further proposed periodic meetings of the people responsible for the fatigue work. These guide lines were agreed on during a preliminary meeting at the College of Aeronautics, Cranfield on 14 September 1951, attended by Dr Plantema, Mr E. J. van Beek (Fokker), Professor W. S. Hemp (CoA) and Mr Bo Lundberg (FFA). It was also decided that representatives of Switzerland and Belgium were to be approached about joining the co-operation.

The date of the Cranfield meeting could be considered as the birth date of ICAF. I think that all of us fully agree, when Professor Schijve states that, regarding Plantema's part in the formation of ICAF, it is fair to say that Plantema founded the Committee.

The First ICAF Conference took place in the NLL Amsterdam on the 25 and 26 September 1952 and was attended by:

Belgium, represented by the Service Technique de l'Aéronautique (STA);

United Kingdom, represented by the CoA;

The Netherlands, represented by the NLL (now NLR);

* NLR Report S.357, August 1949. Written in Dutch, and later translated into English by the Ministry of Supply in the United Kingdom.

Sweden, represented by the FFA;

Switzerland, represented by the Eidgenössisches Flugzeugwerk (F+W).

Altogether there were eleven participants. A suggestion by the representatives of Sweden and the United Kingdom that Dr Plantema should act as chairman was approved. All participants agreed that it would be most convenient to hold the discussions in English.

This First Conference decided upon the organization of the co-operation and the future Conferences. It was decided:

—that the collaboration should initially be limited to aeronautical bodies and laboratories having aeronautical interests;

—to establish a General Centre, for the time being at NLL, which would act as a Secretariat with regard to the collection and distribution of information and reports, with Dr Plantema as the co-ordinator;

—to establish a National Centre in each participating country, namely NLL, CoA, FFA, STA, and F+W, which would collect and distribute information within their own country, and which would prepare conferences to be held in their country;

—to issue periodical reviews by the Secretariat of all activities concerning the collaboration;

—that effective collaboration could only be obtained by regular personal contacts of the persons responsible for the work;

—that an exchange of information on fatigue equipment, programs and test results should be started as soon as possible.

There was an implicit agreement when Dr Plantema suggested that, in view of financial and security restrictions, the collaboration could only be on a completely voluntary basis and should succeed by a common belief that every effort made would lead to benefits for oneself as well as for the others.

The representatives of each country gave a survey of their current work and, as far as possible, a report of their results. The conference was concluded with visits to the NLL and Fokker.

At the Second Conference, which took place at the FFA Stockholm, in 1953, it was further agreed that the yearly Reports and Quarterly Bulletins of the Secretary would be restricted. It was there unanimously decided that the collaborative body should in future be referred to as the International Committee on Aeronautical Fatigue (ICAF), but that the existence of ICAF would not be publicised to the aeronautical press. The national centre of the United Kingdom had been transferred from the CoA to the Ministry of Supply, i.e. to the Royal Aircraft Establishment (RAE), Farnborough.

At the Third Conference (1955, CoA) it was agreed that all documents issued would be stamped with the ICAF Document Number. It was agreed that France and Italy should be invited to collaborate in the work of ICAF.

This was confirmed at the Fourth Conference (1956, Zürich) and an invitation was also extended to Western Germany. Collaboration with a possible ICAO study panel on fatigue seemed to be unnecessary since the ICAF Delegates would undoubtedly be consulted by or participate in such a panel. A similar policy was proposed for the collaboration with the Structures and Materials Panel of AGARD.

Considering the number of attendees at ICAF Conferences, it was decided at the Fifth Conference in Brussels (1957) that no delegation from any country, except the host country, should exceed six people. At this Conference the first contact with Australia was made for collaboration within ICAF.

The Executive of the AGARD Structures and Materials Panel stated at the Sixth Conference in Amsterdam (1959), that they would like to act essentially as another ICAF Centre. After this Conference the First ICAF/AGARD Symposium was devoted to a series of lectures on one main subject (*Full-scale Fatigue Testing of Aircraft Structures*).

It was also possible to combine the Seventh Conference in Paris (1961) with an ICAF/AGARD Symposium (*Fatigue of Aircraft Structures*).

Furthermore, the collaboration with AGARD had made it possible to include at the Eighth Conference in Rome (1963) a review of United States fatigue work, thus preparing the collaboration of U.S.A. within ICAF. Associated with this Conference was the Symposium—*Current Aeronautical Fatigue Problems.*

Certain changes in the AGARD organization made it impossible for AGARD to continue a formal collaboration with a non-NATO body. Therefore, the Symposium (*Fatigue Design Procedures*) held with the Ninth Conference at Munich in 1965 had only the benefit of an informal technical co-operation, whereas the Symposium held with the Tenth Conference in Melbourne (1967) is a purely ICAF Symposium.

So much for the development of the organization of ICAF. It seems that at the First Conference the foundations of ICAF were laid so well that so far virtually no change has been necessary. The following tables and Fig. 1 indicate the success of ICAF.

In the foundation year, 1952, the member countries were The Netherlands, United Kingdom, Sweden, Belgium and Switzerland. West Germany joined in 1956, France in 1957, and AGARD, Italy and Australia in 1958. Finally, the United States of America became an ICAF member in 1964, and in 1965 it was agreed that Australia distribute ICAF information to New Zealand.

Summary of the ICAF Conferences

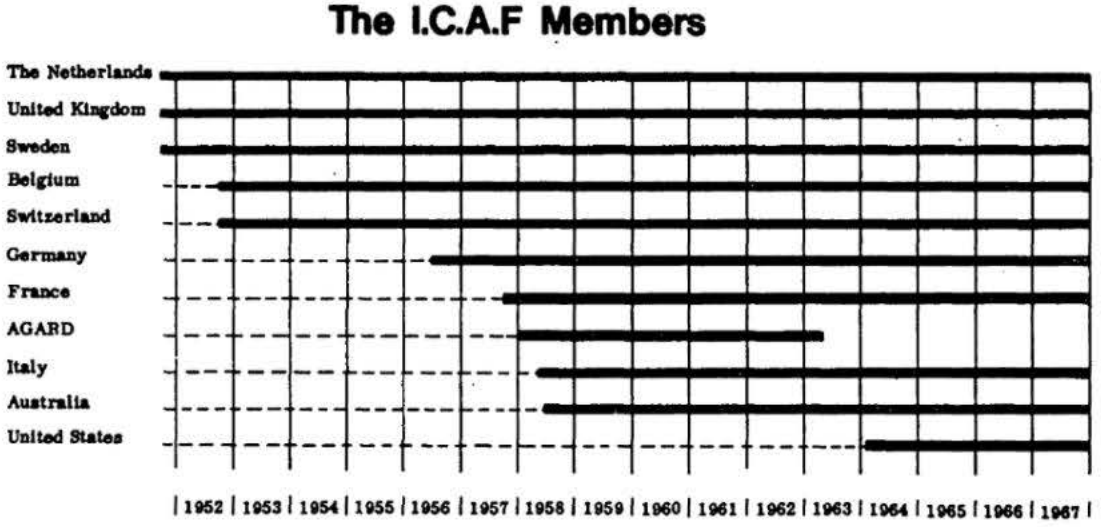
Number	Place	Date	Number of participants	
			Total	Participants of the organizing country
1	Amsterdam	25 and 26.9.52	11	4
2	Stockholm	23 to 25.9.53	23	16
3	Cranfield	2 to 5.1.55	40	27
4	Zürich	23 to 25.5.56	33	14
5	Brussels	1 to 3.10.57	35	11
6	Amsterdam	8 to 12.6.59	29	7
7	Paris	15 and 19.5.61	29	1
8	Rome	22 and 26.4.63	58	6
9	Munich	21 to 23.6.65	74	14
10	Melbourne	16, 17 and 25.5.67	42	24

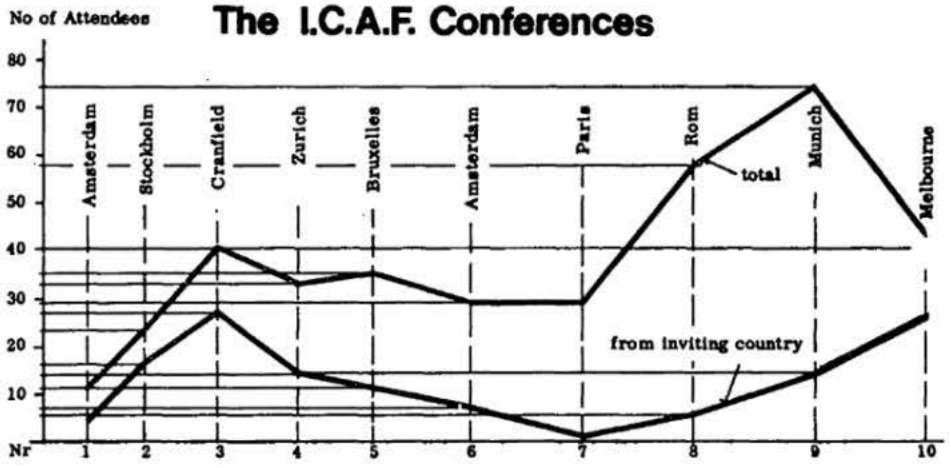
Summary of the ICAF Symposia

Number	Place	Date	Number of participants	
			Total	Participants of the organizing country
1	Amsterdam	9 to 11.6.59	96	36
2	Paris	16 to 18.5.61	80	30
3	Rome	23 to 25.4.63	140	45
4	Munich	16 to 18.6.65	181	54
5	Melbourne	22 to 24.5.67	151	118

The Conferences now take place every second year. Since 1959 the ICAF Conference has been combined with a three-day Symposium, thus allowing a number of specialists to present a total of fifteen to twenty papers which may be published without restrictions. These papers are selected and established on the basis of a number of main topics agreed upon well in advance.

In contrast to the Symposium, the ICAF Conference has, since 1959, been entirely devoted to the confidential National Reviews. The ten Reviews and their discussion require two days. Since 1965 a third day has been reserved for a technical session to discuss the latest results, future problems and tendencies, in order to meet a requirement for increased exchange of opinions. Finally, in a half-day closing meeting, the ICAF delegates discuss the business report and make directives for the two years to come.


The I.C.A.F Members
The Netherlands
United Kingdom
Sweden
Belgium
Switzerland
Germany
France
AGARD
Italy
Australia
United States
1952 1953 1954 1955 1956 1957 1958 1959 1960 1961 1962 1963 1964 1965 1966 1967


No of Attendees
The I.C.A.F. Conferences
Amsterdam
Stockholm
Cranfield
Zurich
Bruxelles
Amsterdam
Paris
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Melbourne
total
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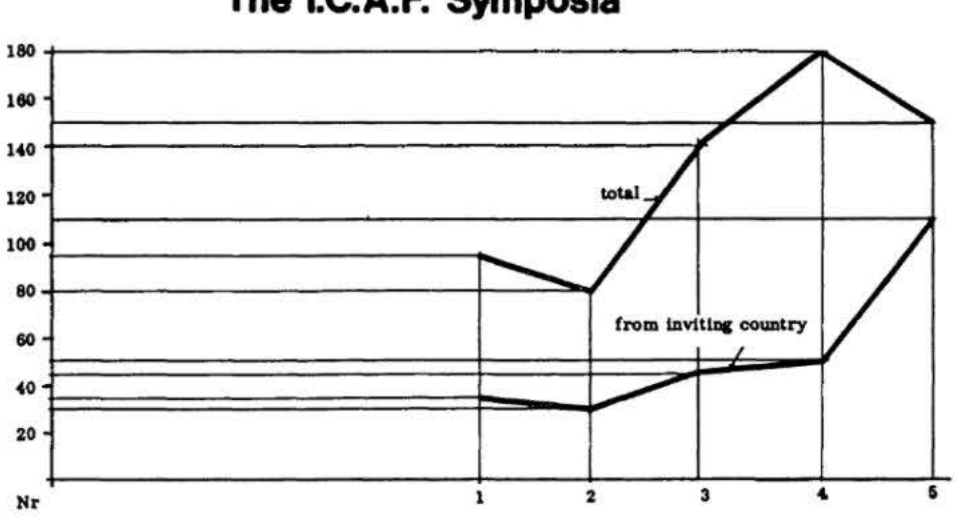
The I.C.A.F. Symposia
total
from inviting country
Nr

Fig. 1

The ICAF Organization consists of a General Centre, managed until recently by the NLR and headed by Dr Plantema, and a National Centre in each member country. The National Centres are represented by the:

[NLR] National Lucht- en Ruimtevaartlaboratorium in The Netherlands
[RAE] Royal Aircraft Establishment in the United Kingdom
[FFA] Flygtekniska Försöksanstalten in Sweden
[STA] Service Technique de l'Aéronautique in Belgium
[F+W] Eidg. Flugzeugwerk Emmen in Switzerland
[LBF] Laboratorium für Betriebsfestigkeit in West Germany
[STAe] Service Technique Aéronautique in France
[MDA] Ministero Difesa Aeronautica in Italy
[ARL] Aeronautical Research Laboratories in Australia and New Zealand
[NASA] National Aeronautics and Space Administration in the United States of America

They provide contacts with institutes, authorities, manufacturers, etc. dealing with fatigue in aircraft design in their country, and also with the General Centre which supplies information to the National Centres. The co-operation is strictly confidential, i.e. any information is submitted to the National Centres only. Publication of or reference to such information is not allowed; the right to do so lies principally in the hands of those from whom it originates.

Confidential reports are dealt with identically. Reports upon the oral exchange of information at the biennial Conferences are also considered to be principally confidential. This procedure became necessary as most of the work carried out is financed by grants from Ministries, manufacturers, etc. and relate to a large extent to military requirements which are obviously confidential. It is due to the restriction of any publicity that a really ideal co-operation is obtained in spite of the often very delicate backgrounds, e.g. crashes.

Co-operation is based mainly upon the oral exchange of information at the biennial Conferences, the quarterly and biennial reports of the General Centre, and the exchange of documents—mainly test reports. All written documents are numbered—at 1 April 1967 there existed 356 documents and in addition, contributions contained in the Conference reports (which included 68 surveys on the activities) amounted to 104.

So much for the formation and growth of ICAF, its structure and its way of working. Despite the fact that there is no formal constitution, and no financial contributions and accounts, it works very well indeed.

The influence of ICAF on the philosophy of aeronautical fatigue in the member countries

In 1951/52 the state of the art in the five foundation countries was quite different. In The Netherlands, Great Britain and Sweden a proper research

in aeronautical fatigue existed, though in different manner; while in Belgium and Switzerland no research of importance had begun, although the problems and the need for research were recognized.

In The Netherlands comparative tests were running on the notch sensitivity of 24S-T and 75S-T alloys, on various types of riveted, bolted and glued joints, on glued and riveted hat-section stiffeners, as well as investigations concerning scatter, the clearance in pin joints, and lugs. This program was continued in the following years. Since 1953 investigations concerning the cumulative damage theory have been in progress and, since 1955, investigations on crack propagation also.

The British delegate reported in 1952 on *ad hoc* investigations of structural components and, in 1953 on research on joints, fretting, interference fit, cumulative damage, stress concentration factor and scatter, as well as on tests on complete aircraft, and on the British research program of load measurements. In 1955 this was proceeding on a large scale, supplemented by a big research program with the aim of preparing a number of data sheets.

The subjects discussed in 1952 by the Swedish delegate were S/N curves of cast aluminium alloy, complete fatigue diagram of 24S-T, scatter of notched and unnotched specimens, cumulative damage, lugs of different materials, clearance between bushes and bolts, surface finish, and hardening of 24S-T and 75S-T. In 1953 Sweden reported on additional research on crack propagation, residual stresses and scatter which were continued in the next years.

The point of view of Belgium was, in 1952, mainly that of the operator. Problems under investigation were helicopter frames and bonded joints. In 1953 tests on an engine mounting structure and on a stroboscopic investigation method were reported.

In Switzerland the world's very first catastrophe of a transport aircraft due to fatigue (27 July 1934, CH 170) did not give inducement to especially investigate fatigue in aircraft design. Thus, in 1952, I could only report on some *ad hoc* tests on riveted joints and on compressor blades, the latter made on a simple air jet facility. In 1955, however, the influence of ICAF was already apparent, as I was able to mention load measurements on fighter aircraft, the influence of defects in 75S-T, program loading on wing spar root joints, Perspex canopy tests and a special test bed.

Not only Switzerland felt the influence of ICAF—all members gained mutually by the collaboration and the exchange of ideas. This exchange caused a perceptible transformation of the philosophy in the different member countries, or accelerated the transformation.

The fruitful diversity of opinions was expanded to the mutual advantage of all members by the admission of other countries to ICAF.

—In 1956 Western Germany reported on program tests and on test specimens built into running motor cars.

—In 1957 France gave knowledge of the investigations of different light alloys, wing fittings, skin/stiffener assemblies and riveted joints.

—Also in 1957 Italy reported on investigations of composite structures.

—In 1959 Australia, although mainly in the position of an operator, gave a survey of the large amount of work in aeronautical fatigue which had been carried out there since the early 1950's on fundamental research, investigations on cumulative damage, light alloys, rate of cycling, surface effects, stress concentration, full-scale tests and in the development of testing techniques.

—Finally, in 1963 the U.S.A. presented its first review, which could not be complete as there were so many laboratories and organizations involved. The main topics included were: fundamental research (surface coating, acoustic emission, strain-ageing, dislocation, crystalline solids under creep and fatigue, mechanism of fatigue, acoustic fatigue, sandwich constructions, thermal fatigue), crack propagation and residual strength (kinetics, high strength metals, notch behavior at low temperature, crack stoppers, statistical evaluation, inspection interval), cumulative damage (non-linear accumulation/reliability functions, statistical methods, prediction for structures) and full-scale tests.

The evolution of the philosophy and of our fatigue knowledge which took place since the setting up of ICAF and which was at least accelerated by its existence, may be highlighted by some headings:

—Gust research and actual loading statistics.

—Dynamic response of aircraft structures.

—Loading of tail units and undercarriages.

—Constant amplitude, program, random, and fatigue-history types of loading.

—Refutation of the linear cumulative damage hypothesis.

—Numbers of flights instead of flying hours, and the importance of the ground-air-ground cycle.

—Resonance tests, flight-by-flight tests, sophisticated fatigue-history simulation.

—Crack propagation and residual strength, crack initiation and crack detection, pre-crack stage investigations.

—Safe-life and fail-safe concept.

—Good detail design, avoiding weak points, to guard against fatigue failures.

—Theory of reliability, statistics, scatter.

—Data Sheets of the Royal Aeronautical Society, etc..

In all of these fields, and in many others not mentioned above, considerable progress was attained and many new perceptions were gained. To describe the state of the art of today would need a full lecture for each of these matters, and therefore I have tried only to demonstrate the evolution by the choice and the form of the above headings.

It is amazing that the contributions of ICAF to the improvement of the understanding of fatigue came into being without setting up a verbal common research program. At the First Conference, Dr Plantema had tated, in accordance with other delegates, that a common research program should be considered as an ultimate goal. Again, in 1953, the suggestion was repeated to carry out tests jointly on subjects of common interest. But why has this not been mentioned since, although the difficulties are much the same everywhere and there is thus much common interest?

The practice proved that the need for a specially organized common research program was already fulfilled and overtaken by the existence of ICAF as such. If we survey the work done in the ten member countries during the last fifteen years as a whole, we recognize that the problem of fatigue in aeronautics was and still is approached from so many different directions and by so many different methods that probably no important aspect is being overlooked. Of course, we are still far from the targets. But to know that we are not alone makes us confident and indefatigable in search of more knowledge and more perception. The fact that we are not alone, but in close contact with colleagues working on the same problems, is in particular the merit of Dr Plantema. By the institution of this Memorial Lecture dedicated to the honour of Dr Plantema the International Committee on Aeronautical Fatigue is expressing its thanks to its founder.