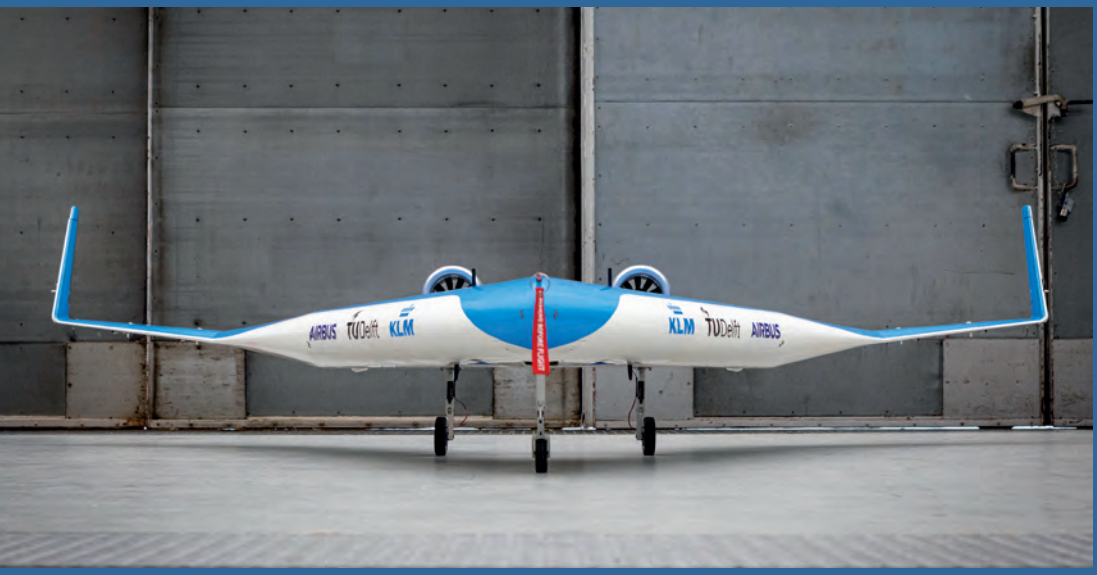
Assessment Committee Report on Research in Aerospace Engineering 2014-2020 Delft University of Technology



October, 2022

ASSESSMENT COMMITTEE REPORT ON RESEARCH IN AEROSPACE ENGINEERING, 2014-2020 AT THE DELFT UNIVERSITY OF TECHNOLOGY

"Become the global hub for aerospace data"

OCTOBER, 2022

Colophon

Title
Assessment Committee Report on Research in Aerospace Engineering 2014-2020, Delft University of Technology

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SUMMARY

The Faculty of AE is one of the largest in the field, and in the areas of (sustainable) aviation and wind it ranks among the best. This is due to clear and strong leadership and to the excellent researchers that were attracted over the years as well as the availability of world class research infrastructure.
The AE-strategy is lacking a focussed strategy and prioritisation. Also, there is lack of clear articulation of how SpE fits in.
The Committee observed an imbalance in the staff; there are too many (tenure track) assistant professors relative to the associate and full professors. Also, regarding tenured staff, the Committee has the impression that the Faculty might be overly conservative with granting promotions to associate or full professors.
The chosen indicators regarding research quality and societal relevance differ between the departments and are not substantiated with data/ evidence
PhD candidates seem generally content and students seem to have a lively community. The success rate of the AE PhD candidate is of concern. Good and adequate monitoring is needed.
In terms of use of data sets the Committee is unable to judge whether the FAIR-principles are followed. Raw data sets at AE are not easily accessible/ easy to find for other (external) researchers.
The topic of diversity at AE focuses mainly on gender diversity and much attention has been paid to promoting this.
Tenure-trackers are much supported, although more could be invested in mentorship. The rubrics for promotion of tenure trackers are not consistent and a lack of transparency is experienced.
Younger – tenured and non-tenured – staff is involved in strategic discussions and faculty meetings around certain topics, although the extend and way this is done differs between the departments.

The Committee recommends the Faculty of AE the following:

- Develop a focussed strategy and prioritisation regarding (sustainable) aviation and wind. Also, make clear how Space (SpE) fits in, because they seem to be overlooked somewhat. Formulate a sustainable execution plan with respect to the strategy.
- One of the absolute strengths of AE is the presence of world class research infrastructure. Make the resulting data accessible according to the FAIR principles. Do consider the acquired data as important research output. Turn AE of TUD into the aerospace datahub of the world.
- Develop a useful system of benchmarking by discussing specific research programmes of AE in a carefully selected international context.
- Increase female presence in the MT, in the board of departments as well as among the rank of full professors. Set a target and be accountable. Also give a formal status to the Diversity Committee.
- Develop and keep track of HR-metrics, e.g. time to promotion from assistant to associate to full professor, success rates of PhD candidates, duration of tenure track. In this respect do not wait too long with promotion to full professor: treat your talent well! Consider career tracks instead of tenure tracks for the young researchers.
- Engage young faculty staff in strategic planning by organising faculty meetings more regularly.
- Concerning PhD candidates: formalise the role of the independent mentor and make sure that mentor and PhD candidate meet at least once a year. With respect to the UGS, create some flexibility in the 45 credit system.

A detailed list of recommendations is given at the end of the Faculty section and at the end of the Department sections.

PREFACE

The Assessment Committee was assigned the task of evaluating the research carried out at the Faculty of Aerospace Engineering (AE) at Delft University of Technology over the period 2014-2020, according to the Strategy Evaluation Protocol 2021-2027.

Over three days, we undertook an in-depth exchange and discussion with staff and management of AE. This enabled us to understand, validate, and refine the initial impressions that we formed through the Faculty self-assessment report.

The evaluation was originally scheduled in the Fall of 2020. It was postponed twice due to Covid-19 and finally took place in June 2022. In the meantime the evaluation protocol changed (from Standard Evaluation Protocol to Strategic Evaluation Protocol) and the year 2020 was added to the evaluation period.

The Committee truly appreciated the hospitality of AE and the open atmosphere in which the interviews took place. The lab tours, as breaks in between the meetings, were both instructive and enjoyable. The support staff, in particular, is thanked for treating us so well during our visit to Delft.

Finally, I wish to thank the Committee members for their hard work, and our secretary Sven Laudy for excellent preparations and support.

Prof. Dr. Ir. Hans van Duijn
Chairman of the Committee

1. Assessment Committee and Assessment Procedures

1.1 Assessment Scope

The Assessment Committee was asked to assess the research of the four Departments that comprise the Faculty of Aerospace Engineering at Delft University of Technology. This assessment covers research in the period 2014-2020. This assessment was initially scheduled for 2020, yet in response to the Covid 19-pandemic postponed until 2021. Therefore, the assessment period includes an additional year, i.e. 2014-2020. The site visit was postponed a second time, now to June 2022. It was decided that no additional material would be added to the self-evaluation report.

In accordance with the Strategy Evaluation Protocol 2021-2027 for Research Assessments in the Netherlands (SEP), the Committee's tasks were to assess the quality, relevance to society, and viability of the research programmes on the basis of the information provided by the Faculty and interviews with Faculty management and research Department personnel. The self-evaluation report, originally written on the basis of the SEP 2015-2021, was adjusted to follow the guidelines specified in the SEP 2021-2027; however, the four specific aspects Open Science, PhD Policy and Training, Academic Culture and Human Resources Policy were covered less integral than formally required by the SEP 2021-2027. As a consequence, the review of these aspects took place separately from the three main criteria.

1.2 COMMITTEE COMPOSITION

The members of the Committee were:

Prof. Dr. Ir. C.J. (Hans) van Duijn, Committee Chair, former rector Eindhoven University of Technology, Professor em., Department of Mechanical Engineering, Energy Technology, Eindhoven University of Technology, The Netherlands.
Prof. H. (Hamsa) Balakrishnan, William E. Leonhard Professor of Aeronautics & Astronautics, former Associate Department Head of Aeronautics and Astronautics, Massachusetts Institute of Technology, USA.
Prof. Dr.-Ing. J. (Jens) Eickhoff. Dipl.-Ing., Professor for Satellite Systems Engineering and Operations, University of Stuttgart, Germany. Airbus Defence and Space GmbH – Space Systems Innovation and New-Space Projects, Friedrichshafen, Germany.
Dr.ir. W.J.B. (Wouter) Grouve, Assistant Professor, Faculty of Engineering Technology, Production technology, University of Twente, The Netherlands
Ir. C.J.M. (Conrad) Hessels, Doctoral Candidate, Department of Mechanical Engineering, Power & Flow, Eindhoven University of Technology, The Netherlands.
Prof. K. (Karen) E. Willcox, Director at Oden Institute for Computational Engineering and Sciences and Professor of Aerospace Engineering and Engineering Mechanics, University of Texas, USA.

A short curriculum vitae of each Committee member is included in Appendix A.

Ir. Sven Laudy of Quicken Management Consultants was appointed as an independent and qualified process consultant to the Committee.

1.3 IMPARTIALITY

All Committee members signed a statement of impartiality and confidentiality to ensure they would assess the quality of the research programmes in an impartial and independent way. Committee members reported any existing personal or working relationships between Committee members and members of the programmes under review before the interviews took place. The Committee discussed these relationships at its first (online) meeting. The Committee concluded that there existed no unacceptable relations or dependencies that could lead to bias in the assessment.

1.4 DATA PROVIDED TO THE COMMITTEE

The Committee received the following detailed documentation:

- Self-evaluation report of the unit under review, including all the information required by the Strategy Evaluation Protocol (SEP), with appendices,
- Previous assessment report 2008-2013.
- Additionally requested data regarding the Faculty strategy (institutional and/or Faculty and/or departmental), policies regarding Academic Culture, Research Integrity, Open Science and Human Resource policies on Diversity and Talent Management.

The self-evaluation report together with the interviews and additional information requested during the site visit were the Committee's key bases for assessment.

1.5 COMMITTEE PROCEDURES

The Committee followed the Strategy Evaluation Protocol, 2021-2027 (SEP). Prior to the Committee meeting, on the basis of their specific expertise two Committee members were appointed main assessors for each programme and were asked to lead the evaluation of that particular programme. These assessors independently formed a preliminary assessment for each programme. Final assessments are based on these, combined with documentation provided by the Faculty, preliminary assessments and interviews. The Committee interviewed the Rector Magnificus of Delft University of Technology, the Faculty Management Team, support departments, and teaching and administrative staff of the Graduate School and research programmes. Interviews took place on June 8-10, 2022 at the Faculty of Aerospace Engineering in Delft. The interview schedule appears in Appendix B.

On September 29, 2021 the secretary of the Committee briefed the Committee on the Strategy Evaluation Protocol for research assessments in an online meeting with the Committee. On May 25, 2022 the Committee participated in a second online meeting to further prepare the site visit. At the start of the site visit, the Committee discussed the preliminary assessments based on the written material. For each department interview, the Committee prepared a number of comments and questions. The Committee also agreed on procedural issues and aspects of the assessment. All Committee members were actively involved in the interviews. After each interview, the Committee discussed comments and recommendations. The Committee also offered a separate advice to the Aerospace Faculty and Executive Board of the TU Delft regarding three additional topics that the Committee was requested to reflect on. The Committee presented preliminary general impressions to the Faculty on the last day of the visit.

Following the on-site visit, the Committee finalised the report through email. Following approval by all Committee members, the Faculty received a copy of the first version with the invitation to correct factual

errors. In response, the Committee discussed these comments, made several modifications to the text and then presented the final report to the Board of the University. This was printed after formal acceptance.

2. ASSESSMENT OF THE AEROSPACE ENGINEERING FACULTY

2.1 THE FACULTY OF AEROSPACE ENGINEERING

The Faculty of Aerospace Engineering (AE) consists of four departments: Aerospace Structures & Materials (ASM), Flow Physics and Technology (FPT) – since 2022, named AWEP during the evaluation period – Control & Operations (C&O) and Space Engineering (SpE). Each of these departments incorporates several sections, covering a specialised research area. The structure of the faculty has been fairly stable during the period of this evaluation, as only the section Aircraft Manufacturing Technologies has been added to the department ASM during the timeframe of the evaluation. The main focus of the Faculty of Aerospace Engineering is to be the faculty of sustainable aerospace engineering, and as such play an essential role in making worldwide aviation truly sustainable.

The Faculty is pursuing its goals by:

1) performing state-of-the-art innovative research, while bringing together the broad expertise from the Faculty and collaborating with chosen strong external partners,
2) striving for world class education, while ensuring the students do not only acquire the necessary technical and scientific knowledge, but also get educated regarding ethical values and sustainability, in order to take these values across the world during their following moves,
3) making sure the fruit of the scientific labour leads to true innovation by connecting to industry: to turn academic results into real applications.

Tables 1-3 summarise some characteristic data regarding scientific output, staff and funding for the years 2014-2020.

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Refereed articles	266	255	339	286	336	344	346
Non-refereed article	1	1	1	2	3	5	7
Books		4	4	4	2		2
Book chapters	20	29	14	13	10	7	2
PhD theses	29	21	36	35	38	36	29
Conference papers	228	253	240	227	240	207	146
TOTAL	**544**	**563**	**634**	**567**	**629**	**599**	**532**

Table 1: Total output Faculty of AE

	2014		**2015**		**2016**		**2017**		**2018**		**2019**		**2020**	
	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE
Assistant professor	48.5	18.8	50.0	19.4	51.4	20.2	53.8	21.4	51.2	20.3	47.3	18.7	53.9	21.1
Associate professor	14.3	5.6	15.0	5.9	16.0	6.1	15.8	5.9	19.2	7.3	22.3	8.8	24.0	9.4
Full professor	16.4	6.0	19.4	7.1	21.2	7.2	21.2	6.8	22.3	7.2	24.4	7.9	24.8	8.3
Researchers	44.1	32.1	46.5	34.4	44.1	33.6	54.2	41.5	53.5	41.5	62.0	46.8	66.5	48.6
PhD candidate	214.6		231.3		244.4		252.9		271.1		256.7		273.4	
Total research staff	**337.9**	**62.4**	**362.2**	**66.8**	**377.1**	**67.1**	**397.9**	**75.6**	**417.3**	**76.3**	**412.7**	**82.2**	**442.6**	**87.5**

Table 2: Staff embedded in the Faculty of AE, which reflect 40% of the actual FTEs, since this is the percentage spent on research (typically)

TOTAL	2014		2015		2016		2017		2018		2019		2020	
	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Direct funding[1]	21329	60%	21129	63%	23755	67%	26013	71%	27194	69%	25065	64%	25732	66%
Research funding[2]	2490	7%	2486	7%	2634	7%	1740	5%	2155	5%	2166	6%	2213	6%
Contract research[3]	11496	32%	8986	27%	9015	25%	8500	23%	9646	25%	10538	27%	9786	25%
Other[4]	352	1%	853	3%	81	0%	267	1%	274	1%	1.347	3%	970	3%
Total funding	**k€ 35666**		**k€ 33454**		**k€ 35484**		**k€ 36520**		**k€ 39269**		**k€ 39116**		**k€ 38702**	

Table 3: Total funding at level of the Faculty of AE. All amounts in k€.

1. Direct funding by the University, obtained directly from the University, and financial compensation for educational efforts.
2. Research funding obtained in national and international scientific competition (e.g. grants from NWO, KNAW, EU/ERC, ESF).
3. Research contracts for specific research projects obtained from external organisations, such as industry, government ministries, the European Commission, and charity organisations.
4. Funds that do not fit the other categories.

General impression[1]

The Faculty of AE is one of the largest in the field, both in terms of staff and students. In the areas of (sustainable) aviation and wind it ranks among the best. This is due to clear and strong leadership and to the excellent researchers that were attracted over the years as well as the availability of world class research infrastructure. In both areas AE is agenda setting in Europe. In short, AE is a great school with a global reputation.

This holds in particular for the departments FPT, C&O and ASM. The SpE department, which is overwhelmed by MSc-students, needs to bring in

[1] Some of the developments mentioned in the paragraph are topics from the last two or three years, and not during the (whole) evaluation period, e.g. the overwhelming number of MSc students at SpE, leadership on diversity, AI and big data.

more research focus to align with the reputation and research quality of the other departments. Here work has to be done.

In general, the Committee met staff that is proud to be part of AE. Also, the Committee is very positive about leadership on diversity and the way young talented researchers were attracted.

The Committee learned that reasons to come and stay in Delft include – indeed – the excellent scientific infrastructure, the quality of the people and the international atmosphere that characterises TUD.

Though the funding for contract research did not show an increase in the assessment period (11.5 MEuro (2014), 9.8 MEuro (2020)), the programmes on sustainable aviation and wind are well-positioned in the current national growth fund (Groeifonds) which will lead to a significant increase of the funding.

Some of the departments have a thoughtful and productive approach to AI and big data. In particular the department of Flow Physics and Technology (FPT) presented clear ideas on how AI can be used to augment the large experimental datasets that are generated in their facilities.

There is a strong culture of collaboration within and between the departments, and across the university. The external collaboration with industry in aviation and wind is also well established.

The Committee appreciates that AE is tackling the challenge of many Bachelor's and Master's students, especially in space.

In terms of outreach the Committee thinks that the Faculty of AE could be promoted more internationally; many awards globally are available, but efforts are needed here.

Strategy

The Committee was briefed by the rector on the TUD-wide strategy to cooperate with institutes that are complementary. The TUD convergence-strategy is well-articulated. The Committee is happy to hear that some elements of the convergence-approach came back in discussions with tenured staff (e.g. modeling pilots). This type of collaboration is a great opportunity to modernise and expand the classical engineering disciplines.

The AE-strategy is lacking a focussed strategy and prioritisation; a sustainable execution plan is not apparent. A common direction is needed to align the four departments [1] [2]. Within this alignment there will still be enough room for bottom-up initiatives.

Also, there is lack of clear articulation of how SpE fits in; it seems overlooked in the Faculty-wide strategy, resulting in too little priority. The Committee realises there are three departments on aviation (including wind) and one on space, so it certainly makes sense to give more attention to aviation, but nevertheless a holistic approach is needed to align space better with the Faculty strategy.

Staff

Tenured staff see TUD as a great place to work for reasons of their research autonomy, collective use of excellent research facilities, and size of the organisation that gives possibilities for collaboration with many experts.

The Committee observed an imbalance in the staff; there are too many (tenure track) assistant professors relative to the associate and full

[2] The numbers between the brackets throughout the main text refer to the list of recommendations at the end of each section.

professors, partly due to recent growth. It is necessary to have a plan in place how to manage this. Appointing more full professors is certainly one of the possible solutions, as the Committee learned that at AE full professor positions can be opened without an existing position becoming vacant.

Benchmark

A solid benchmark was missed by the Committee. This is partly explained by the fact that MIT could not be visited due to reasons of Covid-19. Nevertheless, the Committee thinks that the benchmark-exercise needs a more serious approach. It is recommended to discuss specific research programmes of AE in a carefully selected international context [2]. As a side remark: MIT seems not the obvious choice for AE because of difference in size and type of school (private vs. public). Georgia Tech, which was initially planned as a benchmark (but not conducted because of the pandemic) might be a better US benchmark.

Self-evaluation Report

The self-evaluation report was of low quality. Due to lacking coherence (it was written like four independent sections with no combined strategy and synergy), parts of the report not being accurate, and not up-to-date with the many recent developments (with chances to repair in the period between the first postponement and the actual site visit) it was hindering the assessment process. Much Committee-time before and during the site visit was used to go through the material that was (in part) outdated (as one department head was saying: don't read the material, just look at my presentation). With this AE sells itself short; AE is actually doing a lot better than the report shows: many strengths that were not apparent from the report were only fixed during the interviews.

Using metrics

The chosen indicators regarding research quality and societal relevance differ between the departments and are not substantiated with data/ evidence. The quantitative data not only seem to be absent, but a culture of not caring for (HR-)data seems to exist, e.g. the wrong dropout rate of PhD students is mentioned in the self-evaluation report, and time to promotion (assistant-associate-full professor) and duration of tenure tracks is not instantly clear at the interviews.

The Committee recommends doing more with keeping track on the metrics and to create a better awareness of the role of data and accessibility [3].

2.2 PhD programmes and AE Graduate School

It is the ambition of the University Graduate School (UGS) to train highly skilled doctoral graduates. Consistent with the agreements of the Bologna Process regarding the doctoral training as a third cycle of tertiary education, the UGS has developed its educational programmes into a distinct part of the academic training leading to a doctoral degree. The mission of the TUD Graduate School is to prepare and train doctoral candidates to become highly qualified, autonomous, and leading researchers and skilled professionals with awareness of scientific integrity and ethical behaviour and to ensure that the doctoral process is transparent, systematic and effective. Besides this, the UGS recognises scientific supervision as the key element of the research environment and doctoral training.

The success rates of the PhD candidates at Faculty level are found in Table 4.

Enrolment				Success rates						
Starting year	**Male**	**Female**	**Total (female + male)**	**4 years**	**5 years**	**6 years**	**7 years**	**Total**	**Not yet finished**	**Discontinued**
2011	86%	14%	36	3%	50%	64%	72%	78%	11%	11%
2012	90%	10%	21	10%	52%	67%	71%	71%	10%	19%
2013	78%	22%	43,5	7%	51%	72%	75%	77%	9%	14%
2014	86%	14%	42	7%	50%	62%	67%	67%	21%	12%
2015	81%	19%	36	22%	42%	61%	x	61%	25%	14%
2016	76%	24%	42	5%	29%	x	x	29%	62%	10%
2017	83%	17%	48						83%	17%
2018	83%	17%	52,5						89%	11%
2019	58%	42%	36						97%	3%
2020	58%	42%	55						98%	2%

Table 4: Success rates of the PhD candidates at Faculty level

PhD candidates seem generally content and the atmosphere under the PhD students is good. Professors are very approachable, and no strict hierarchy is felt.

In the previous assessment it was reported that there was not much involvement in the PhD community, but this has improved much since then; students seem to have a lively community, which is active, and social activities, such as outings/afternoon drinks, exist.

The Committee considers the independent mentor a useful concept that should be formalised [4]. Some mentors contact the student regularly, while in other cases it is the student that needs to take the initiative. It is sometimes used to "let off steam" or discuss how to tackle problems they have with their supervisor. One soft recommendation could be to have a system of regular meetings with the mentor and the PhD student, e.g. once a year [5].

Though the UGS is a good first step in the development of the PhD education at TUD, the success rate of the AE PhD candidate is of concern, see table 4. Good and adequate monitoring as to why the drop-out rate

is pretty high and why the time-to-completion is so low, is missing and should be higher on the agenda. Especially, with a growing Faculty, tracking becomes particularly more important, e.g. from the "discontinued" group it is not clear whether it is the student's own choice or due to go-no go. It is recommended to keep better track of why this happens.

Each PhD student has two supervisors and the four-eyes-principle is apparent, at least on paper. PhD candidates have a different experience, though. In practice it depends on the supervisor and group whether this really is true. It was reported that in some cases the PhD student only talks with one of the supervisors.

In the previous assessment it was reported that it is not very clear to PhD candidates how many papers are expected from them to graduate. Currently, the students don't seem to be too worried about the requirements. They set up a plan at the beginning together with supervisors and review it during the project (and make changes accordingly).

The Committee particularly likes the policy of the Faculty on allowing students to write theses in which (1) chapters are more stand-alone submitted/accepted/ published journal publications, instead of requiring students to re-write work in a new coherent storyline; (2) chapters can be made out of "unsuccessful" research (which did not provide publication worthy results, but still is valuable content). This will help in shortening students time to finish and reduce "final year" stress.

45 credits for the courses seems to be doable. However, some PhD students might need to do master's courses (and pass them) which consumes a lot of time. For some PhD students plenty of suitable/useful/interesting courses exist, but for others (investigating newer research topics) not. It is therefore recommended that there is

some flexibility in the 45 credit system [6]. Professional skill courses were perceived to be generally useful.

2.3 Open Science

The overall policy for Open Science at the TUD-level is the so-called green route. New data stewards are found to be useful to internal staff.

AE should make all its scientific data available in a FAIR (thus accessible) way [7]. This would definitely contribute to its scientific reputation and scientific output.

In terms of use of data sets the Committee is unable to judge whether the FAIR-principles are followed. At least, the use of scientific datasets is not being tracked. There also seems to be no active independent checking whether research can be reproduced from the stored datasets.

Raw data sets at AE are not easily accessible/ easy to find for other (external) researchers (the ASM department is an exception), which is a missed opportunity due to the large amount of experimental data that the department generates through its excellent (and unique) experimental facilities. The data that are generated at AE are considered extremely valuable and could make AE the aerospace data hub of the world [8].

2.4 ACADEMIC CULTURE

Research integrity

Research integrity at the Faculty of AE follows the TUD-wide integrity policies. TUD strives to be articulate and explicit with respect to its ideals, values, principles and responsibilities and the means it utilises to implement its vision in day-to-day practices, procedures and operations. TUD's integrity policy entails the 'Code of Conduct', several regulations to support students and staff. TUD offers training modules for new PhD students on the topic of scientific integrity and has instated a Research Integrity Committee. This committee handles complaints arising from suspected breaches of academic or scientific integrity that may occur within the organisation. New PhD students and new academic staff take part in training sessions that include research ethics. The general impression of the Committee is that adequate structures and procedures are in place to deal with problems concerning research ethics. The Committee observed no issues with respect to research integrity.

Social safety and inclusivity

TUD strives to be a safe, diverse and inclusive learning and working environment for all staff and students. TUD has articulated a set of principles and long-term goals regarding inclusion in the TUD Diversity & Inclusion (D&I) policy framework. At the Faculty of AE these principles are followed and implemented. The Diversity office that is in place at AE also deals with inclusion topics, which is very much appreciated by the Committee. See also the next section.

2.5 HUMAN RESOURCES POLICY

Diversity

The Committee was impressed to see the Faculty leading the University in initiatives on diversity and PhD student wellbeing. The Committee believes that the Faculty's current focus on sustainable aviation will help recruit a more gender-diverse research community.

The Faculty has always been a very international community (esp. among students), and the international diversity of the staff also is improving. The Committee thinks that more work could be done on integration of different groups, building on current efforts.

The topic of diversity at AE focuses mainly on gender diversity and much attention has been paid to promoting this, especially by the dean. The stated target of 30% women in 2025 is very ambitious!

In spite of good intentions though, the Committee saw only one female full prof in the MT. Although the Committee appreciates the fact that the former dean was a female, which is rare, particular at a Technical University, it is not enough. To empower women, it is very important that (more) females are present in the MT, department boards, and as full professor [9].

During the interviews the Committee learned that a vacancy is not strictly necessary to add full professors to the organisation. With this in mind, it should be possible to have more female full professors than the current two. The Committee thinks that a more radical change is needed to get gender diversity working. With the current approach it will take another 15 to 20 years to have an even gender balance in all different staff levels.

The Diversity Office is contributing positively and should be formally acknowledged [10]. The Committee recommends putting more weight to the committee, by

1) giving resources to the committee,
2) making it a standing committee in the Faculty, with a formal recognition of the role of its chair, e.g. as a member of the MT,
3) allocating time to the members of the committee, and
4) adding a full professor – even if this professor is a male – to the committee to add more power.

Attracting staff

The Faculty strives to attract excellent people, that are aspired by sustainability. The vacancy texts are intentionally not too detailed, to reach a larger group of potential candidates. The Faculty has been able to attract many new staff members – 33% growth in the period 2019 – May 2022: the majority on tenure track assistant professor level. Although the inflow of this particular group is very diverse, more focus on diversity on the associate and full prof level is still needed. Despite the large growth over the past years, there are still many open vacancies which may prove hard to fill given the global war on talent.

As a side note, it struck the Committee that much attention is being paid to attracting talent, but less on keeping talent. Keeping staff and fostering talent potentially deserves more attention within AE. Though the younger staff is generally quite content, there are concerns regarding the career planning system in place.

Career planning – tenured staff

The Committee was surprised to learn that it is possible to get tenured and then be assistant professor for years without a clear prospect to get promoted. It was perceived that career development depends too much

on the ability to bring in (large) research grants. Given the competitiveness in some fields, especially where the funding opportunities are rare, this may lead to demotivated – or even disillusioned – staff. Management should therefore think of ways how to help the staff get promoted; perhaps by encouraging careers with more focus on education.

It would be valuable to collect and review data concerning promotions. The Committee has the impression that the Faculty might be overly conservative with granting promotions (but data on this is missing). Getting this process refined is even more important with the looming shock wave of assistant professors that is ahead of the Faculty (not yet visible in Table 2). The Committee recommends not to wait too long with promotion to associate or full professor, especially for female staff; role models are needed here [11].

The Committee has the impression that promotion criteria – partly based on clear metrics – are not well-defined. Tenured staff is not experiencing it as unfair per se, but as a grey area. The criteria as well as the procedure for promotion should be clarified to staff to avoid them from getting demotivated or leaving. The Committee learned that ASM is moving towards to a PI-system, which would be a great opportunity to reflect on the current practice and implement improvements. During the interviews the Committee learned that AE is currently setting up a strategic system of reviewing personnel and resources ("Vlootschouw"). As a part of such a system, the Committee recommends HR to review each assistant professor some years after getting tenured, to provide feedback where they are on the path to becoming an associate professor [12].

Tenure trackers

Tenure trackers are offered personal development courses (e.g. how to supervise (PhD) students or how to establish collaboration). This is seen as useful. In general, tenure-trackers are much supported and an open-door policy is experienced. More could be invested in mentorship, though. The rubrics for promotion of tenure trackers are not consistent; it is necessary to clarify what is needed for tenure trackers to make the next step in their career. Also, a lack of transparency is experienced: some rules exist, but are not always communicated.

One side-note the Committee wants to make is that tenured assistant professors are quite uncommon outside Europe, where tenure often comes with a promotion to associate professor. Being perceived as tenure trackers, this can impact the career of assistant professors with tenure as they are not considered prime candidates for editorial boards, review committees, visiting professorships etc.

Involvement of staff

Younger – tenured and non-tenured – staff is involved in strategic discussions and faculty meetings around certain topics, although the extend and way this is done differs between the departments. The Committee recommends to further engage (young) staff in shaping the future by organising these meetings more regularly [13]. The Committee learned that a survey was held among staff which resulted in coaching sessions and a change in management style. The Committee considers this to be very positive.

As a final note, the Committee recommends sharing good practices in the wider TUD community. Here, data collection becomes important in order to benchmark AE against other Faculties.

2.6 FACULTY'S EXTRA QUESTIONS

QUESTION 1: "TO WHAT EXTEND DO YOU SEE THE CONNECTION BETWEEN THE VARIOUS RESEARCH TOPICS, BOTH WITHIN THE FACULTY AND BEYOND, AND HOW CAN THIS BE FURTHER STRENGTHENED?"

The theme of "Clean Aviation" is well chosen. It connects three departments (all, except space) and it puts AE in a leading role in Europe. There is ample room for collaboration between departments. For example about the development of morphing wings (like the smart-X programme of the Faculty) to improve the efficiency of aircrafts. Such technologies involve aerodynamics, control, as well as materials and structures. The TU developed Flying-V is also a nice example where input from different departments is required to make progress. It all starts with the Faculty of AE formulation its research focal points within or between clean aviation/ wind energy/ space. Then connections between departments can be strengthened by supporting specific projects that fit AE's strategic goals (e.g. hydrogen propulsion). Hence, this is a bottom up – top down process, for example by means of internal project calls which require involvement of at least two departments. Alternatively, the Faculty could encourage shared PhD students, collaborative MSc student projects or even appoint joint tenure trackers.

Beyond the Faculty, AE fits very well in some of the global TUD initiatives. For instance, AE should play a leading role in AE on sustainable mobility. This is a matter of setting priorities.

Question 2: "How could the four Aerospace Engineering focus areas be further strengthened, in relation to the societal task of faculty and its departments?"

This question relates to the first one. The Committee believes that if the Faculty of AE wants to create more societal impact it should, to this aim, develop a strategy and set priorities. At particular at this point in time, where new 'sectorplannen' are being considered and funding for large scale scientific infrastructure and 'groeifonds' means are available, there are ample opportunities. The Committee advices two design two large scale projects (with large scale impact) within aviation/ wind/ space.

The Committee hesitates to provide a list of topics because it feels that the Faculty, with strong leadership of the Dean and the MT, together with its internationally renowned research staff, should be able to come up with specific plans. Hence, the Faculty should, in particular, mobilise the intellectual power of the younger generation of scientists and benchmark their ideas against leading institutions in Europe, e.g. Stuttgart, and the US, e.g. Georgia Tech). The resulting pivoting projects determine the scope of the Faculty for the next decade (at least).

Question 3: "How could the faculty and its departments best determine their future strategy, in particular on focusing more on certain Key Performance Indicators (e.g. the ratio PhD/MSc vs. academic staff; funding possibilities etc.)?"

In essence, the first part of the question was addressed in the previous answers: prioritise and limit the number of research focal points, expand and modernise the necessary infrastructure, and stimulate interaction between the departments. In this way, the Faculty could be more agenda setting in Europe.

Though Faculty-wide benchmarking seems not so useful, regularly benchmarking the departments could certainly be beneficial. For instance between SpE and the Stuttgart Space Institute.

The use of KPI's, or metrics in general, is not well embedded in the Faculty and should be improved. Several statements in the report mention this (e.g. [3]). The Committee wishes to emphasise that KPI's are not targets on their own ('afvink/ afreken cultuur'), but rather instruments to monitor developments. In the end it is up to TUD (central) or AE (Faculty) to select useful KPI's, and, equally important, HR-metrics.

2.7 LIST OF RECOMMENDATIONS

The Committee recommends the Faculty of AE to:

[1] Develop a holistic and sustainable execution plan that gives focus to the strategy;
[2] Discuss specific research programmes of AE in carefully selected international context;
[3] Doing more with keeping track on the metrics and to create a better awareness of the role of data and accessibility;
[4] Formalise the role of the independent mentor;
[5] Have a system of regular meetings with the mentor and the PhD student;
[6] Create some flexibility in the 45 credit system;
[7] Make all its scientific data available in a FAIR way;
[8] Create the aerospace data hub of the world;
[9] Increase female presence in the MT, department boards, and as full professor;
[10] Formally acknowledge the Diversity Committee;
[11] Not to wait too long with promotion to full professor, especially for female staff;
[12] Review each assistant professor some years after getting tenured;
[13] Further engage (young) staff in shaping the future by organising strategic meetings more regularly.

3. Assessments of Individual Research Departments

The Committee assessed the four research Departments of the Faculty of Aerospace Engineering of Delft University of Technology:

- Aerospace Structures and Materials
- Flow Physics and Technology (formerly known as: Aerodynamics, Wind Energy, Flight Performance and Propulsion)
- Control and Operations
- Space Engineering

The detailed assessment of each Department follows[3].

[3] The assessments of the departments are in the order in which they appear in the self-evaluation report

3.1 RESEARCH DEPARTMENT OF AEROSPACE STRUCTURES AND MATERIALS (ASM)

Head of Department	Prof. Dr. Ir. Rinze Benedictus
Research staff 2020	29.4 Research FTE (excluding PhD)

The self-assessment report states: "The mission of the Aerospace Structures and Materials department is to enable (certification of) sustainable aerospace applications by life cycle engineering novel lightweight materials and reliable lightweight structures". This is achieved by innovating throughout the entire value chain from material development, via engineering and manufacturing, to the design and certification of structures for sustainable aviation and spaceflight.

The research activities of the department are subdivided in 16 different research areas, which are listed along the value chain from materials to structures: 1) Self-Healing Materials, 2) Smart Materials, 3) Polymers and Matrix Systems, 4) Metals by Design, 5) Multiscale Composite Manufacturing Technologies, 6) Composite Welding,) Multi-Scale Virtual Testing, 9) Fatigue and Damage Tolerance, 10) Fracture and Damage of Adhesively-Bonded Structures, 11) Structural Integrity and Reliability, 12) Non-Destructive Testing and Structural Health Monitoring, 13) Prognostics and Condition-Based Maintenance of Composite Structures, 14) Design-Oriented Analysis of Composite Structures, 15) Stability and Crashworthiness, and 16) Smart Aeroelastic Structures.

These research areas are explored by four sections: Novel Aerospace Materials (NovAM), Aerospace Structures and Computational Mechanics (ASCM), Structural Integrity and Composites (SIC), and since 2018, Aerospace Manufacturing Technologies (AMT). The connection between the research areas and the four different sections is not elaborated in the self-assessment report.

The research staff is composed of 8.9 FTE scientific staff[4], 20.5 FTE researchers and 88 PhD candidates (2020).

Table 5 shows the demonstrable research output of the ASM department.

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Refereed articles	96	100	115	99	129	132	123
Non-refereed article				1	1		
Books		2	1	1			1
Book chapters	2	15	4	2	2		1
PhD theses	12	8	10	8	8	8	8
Conference papers	46	66	56	36	43	38	34
TOTAL	**156**	**191**	**186**	**147**	**183**	**178**	**167**

Table 5: Total output of the ASM department

The composition of the research staff at level of ASM is given in Table 6.

	2014		**2015**		**2016**		**2017**		**2018**		**2019**		**2020**	
	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE
Assistant professor	12.3	4.6	13.4	5.1	11.9	4.6	12.5	5.0	10.8	4.3	8.2	3.3	9.5	3.8
Associate professor	4.0	1.6	4.3	1.6	5.0	1.7	4.8	1.6	6.0	2.2	7.1	2.8	8.5	3.4
Full professor	3.5	1.2	4.3	1.7	4.6	1.7	4.0	1.4	4.3	1.6	5.0	1.9	4.3	1.7
Researchers	19.9	15.8	21.8	17.0	17.2	13.1	20.3	15.6	22.5	17.7	24.9	19.8	25.8	20.5
PhD candidate	65.1		64.7		65.5		73.2		79.8		81.9		87.7	
Total research staff	**104.7**	**23.2**	**108.6**	**25.4**	**104.1**	**21.1**	**114.8**	**23.6**	**123.4**	**25.8**	**127.1**	**27.8**	**135.8**	**29.4**

Table 6: Staff embedded in the ASM department

[4] Comparable with WOPI categories HGL, UHD and UD; tenured and non-tenured staff.

The total funding of ASM is given in Table 7.

TOTAL	2014		2015		2016		2017		2018		2019		2020	
	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Direct funding[1]	4179	46%	4199	49%	4554	54%	4743	58%	4752	55%	4768	50%	5129	57%
Research funding[2]	606	7%	649	8%	721	8%	458	6%	455	5%	512	5%	368	4%
Contract research[3]	4274	47%	3735	43%	3456	41%	2935	36%	3543	41%	4061	43%	3147	35%
Other[4]	-58	-1%	41	0%	-243	-3%	67	1%	-59	-1%	150	2%	378	4%
Total funding	**k€ 9001**		**k€ 8624**		**k€ 8488**		**k€ 8204**		**k€ 8692**		**k€ 9492**		**k€ 9023**	

Table 7: Total funding at level of the ASM department. All amounts in k€.

1. Direct funding by the University, obtained directly from the University, and financial compensation for educational efforts.
2. Research funding obtained in national and international scientific competition (e.g. grants from NWO, KNAW, EU/ERC, ESF).
3. Research contracts for specific research projects obtained from external organisations, such as industry, government ministries, the European Commission, and charity organisations.
4. Funds that do not fit the other categories.

RESEARCH QUALITY

The quality of research at ASM is considered high. The department has a good publication record, which shows an intended shift from conference proceedings to peer-reviewed journal articles in established journals during the assessment period. In addition, several ASM researchers and students have received international awards. The numerous invitations for staff members to provide guest lectures at conferences, workshops, and at other universities, as well as the strong presence in international well-reputed editorial and advisory boards provide another indicator of the high research quality.

The ASM department has excellent experimental facilities that cover the full range from molecule to sub-structure. The available equipment is of a high quality and, therefore, also used by other departments and faculties in Delft. The support staff in the labs is of a high level (some with a PhD degree), which contributes to the overall quality of the

experimental work. It was appealing to see that the facilities and support staff are also available for students to work on their own projects (even outside the scope of their educational programme). This gives rise to an entrepreneurial atmosphere and encourages collaboration and possible spin-off companies.

As a last note, the department covers a broad range of research fields, with polymer synthesis and material development on the one end, and computational optimisation and structural design on the other. The breadth of the activities is well illustrated by the exhaustive list of research areas as provided in the self-assessment report. Although there are probably ample examples, the synergy between the different activities was poorly elaborated in the report and during the site visit. It is unclear how the research fields are defined, how these connect to the four research sections, and how the areas fit with the overall mission of the department.

RELEVANCE TO SOCIETY

ASM is very well connected to the National and European aircraft (manufacturing) industry, with a substantial part of their projects funded directly of via European programmes (e.g. CleanSky). The department has a long-standing track record of bringing research innovations to industrial applications; the ultrasonic welding process is an appealing recent example. Under the period of assessment three start-ups were founded. The connection to SAM|XL provides additional opportunities for valorisation through spin-offs and collaboration with industry. Further, ASM actively contributes to the development and standardisation of test protocols, e.g. for testing fatigue delamination or for the healing performance of polymers, and of software for the analysis of new materials, the design of aircraft configurations, or the non-destructive inspection of structures. Overall, the research in the

department leads to innovations and strengthens the National and European (aircraft) industry.

The department has large number of PhD students, part of which will find jobs in industry further underlining the department's relevance to society. In addition, the staff reaches out to a broader audience (taxpayer) via interviews on TV, and in magazines.

VIABILITY

Considering the breadth and depth of the research as well as the close connection to industry, the ASM department should play a leading role in the development of sustainable aviation by introducing novel materials and manufacturing techniques, improved design, inspection, and certification methodologies, as well as new aircraft concepts. The recent opening of the SAM|XL, where innovations can be tested in an industrial manufacturing environment, opens further opportunities for the department. A strategy (including funds) to carry promising innovations from low to high TRL is recommended. Such a strategy could also improve the coherence in the department [14].

The Committee has two main concerns regarding ASM's viability: a lacking long-term strategy / vision and an unstable organisation.

Starting with the former, the long-term vision and strategy of the department is unclear for the Committee. The vision is poorly elaborated in the self-assessment report; it is covered by one paragraph and formulated in generic terms only. During the site visit and interviews, the Committee did not get a clearer picture, with vision and strategy mostly limited to umbrella terms such as: artificial intelligence, biomaterials, the engineer of the future, bio-inspired engineering. The presentation of the management team did emphasize a focus on Artificial Intelligence and Bio-Inspired materials and engineering ("AI +

BI = ASM") for the coming years. However, the specifics (where, what, and how?) and the rationale (why?) behind this focus remained vague.

More focus is needed, especially on a big theme such as AI, where developments are fast and cover a broad range of fields, including material design (e.g. polymer synthesis, alloy development, hierarchical structure design), process simulation and control (e.g. permeability predictions, data-driven process control), as well as computational design and optimisation. The Committee strongly recommends formulating a long-term strategy for the department based on a comprehensive benchmark against other institutes to identify where the department can make the most impact [15]. The strategy should lead to a long-term investment plan for both personnel and facilities, both experimental and computational.

Regarding the personnel, the ASM department has the lowest percentage of full professors in the Faculty, especially related to the number PhD students. It is highly recommended to promote associate staff to full professors or to hire new full professors to better align with other departments in terms of the ratios between PhD student per full professor [16]. This would lead to a reduction of work load for the full professors and, thereby, reinforce the department leadership to help define and execute the long-term strategy.

The second concern of the Committee is related to organisation. During the interviews, the Committee learned that an elected MT will be implemented as of September 2022. ASM is pioneering with this elected MT, not only within the Faculty but for the whole of TUD. The Committee is not against such a democratic process per se – the intention of involving junior staff is applauded – but sees a number of pitfalls. These are related to:

[1] possible conflicts of interest, e.g. with regard to promotion: associate professors could be promoted by assistant professors,

[2] an imbalance of power and authority, where junior members of the MT feel uncomfortable speaking their mind, and
[3] a potential lack of experience in formulating and executing the overall department strategy.

In general, the Committee is greatly concerned because the change seems rushed and not well thought through. Combined with the poorly articulated strategic vision, this entails a long-term risk for the department. Before implementation of the elected MT, the Committee therefore recommends to identify and think through potential pitfalls that may hamper the overall management of the department [17].

Overall, the Committee felt that the ASM department did not show the teamwork and shared vision among the associate and full professors that was evident in the other departments."

LIST OF RECOMMENDATIONS

The Committee recommends ASM to:

[14] Develop a strategy to carry promising innovations from low to high TRL;
[15] Formulate a long-term strategy for the department based on a comprehensive benchmark against other institutes;
[16] Promote associate staff to full professors or to hire new full professors to better align with other departments in terms of the ratios between PhD student per full professor;
[17] Identify and think through potential pitfalls of the elected MT.

3.2 RESEARCH DEPARTMENT OF FLOW PHYSICS AND TECHNOLOGY (FPT)

Head of Department	Prof. Dr. Ir. Leo Veldhuis (since June '21)
Research staff 2020	24.4 Research FTE (excluding PhD)

According to the self-assessment report, the Flow Physics and Technology department (FPT, formerly known as: the Aerodynamics, Wind Energy, Flight Performance and Propulsion department) covers the fundamental disciplines of Aerodynamics, Thermodynamics, Aeroacoustics and their synergistic application to designing sustainable aircrafts, sustainable engines, efficient & quiet power systems and wind energy. FPT spearheads the sustainability goals of the faculty. The application of the above-mentioned fundamental disciplines to wind energy complements the sustainability goals of the university and society at large.

The FPT research covers a broad spectrum, ranging from fundamental physics (fluid dynamics, optics, acoustics, etc), to novel concepts and applications (e.g. plasma flow control, flameless combustion, acoustic absorbing metamaterials), up to aircraft design and system optimisation (e.g. novel aircraft and rotorcraft concepts, hybrid-electric propulsion integration and mission optimisation). FPT further leverages aerospace technologies to advance research on wind energy systems (e.g. efficient wind farms, smart rotors, low-noise blades, airborne wind power) and sports aerodynamics (e.g. aerodynamics of cyclists, skaters).

The research strategy of FPT is to enhance the value of their research utilising the proximity among chairs and staff members with complementary competencies. The department's approach to integrating research is based on a shared set of research facilities

(experimental and computational) as well as overarching scientific problems amongst research groups.

The department has three sections, Aerodynamics (AERO), Flight Performance and Propulsion (FPP), and Wind Energy (WE), in conjunction with the FPT laboratories.

The research staff is composed of 13.1 FTE scientific staff[5], 11.2 FTE post-docs and 88 PhD candidates (2020).

Table 8 shows the demonstrable research output of the FPT department.

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Refereed articles	91	73	113	76	80	87	95
Non-refereed article		1			1	4	4
Books		1	1		2		1
Book chapters	7	6	4	3	6	3	
PhD theses	7	9	15	16	12	13	7
Conference papers	76	90	64	67	79	78	60
TOTAL	**181**	**180**	**197**	**162**	**180**	**185**	**167**

Table 8: Total output of the FPT department

[5] Comparable with WOPI categories HGL, UHD and UD; tenured and non-tenured staff.

The composition of the research staff of FPT is shown in Table 9.

	2014		2015		2016		2017		2018		2019		2020	
	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE
Assistant professor	14.2	5.6	14.0	5.6	15.8	6.3	16.5	6.6	16.1	6.3	14.3	5.6	18.1	7.0
Associate professor	3.8	1.5	5.0	2.0	5.0	2.0	5.0	2.0	5.9	2.4	6.3	2.5	7.5	3.0
Full professor	6.0	2.1	6.8	2.4	7.0	2.4	7.6	2.5	8.0	2.5	9.1	2.9	8.8	3.1
Researchers	13.0	9.0	12.0	8.1	8.8	6.2	12.2	9.0	12.8	9.6	16.6	12.1	16.2	11.2
PhD candidate	73.0		76.4		78.9		79.8		84.2		81.1		88.2	
Total research staff	**109.9**	**18.2**	**114.1**	**18.1**	**115.4**	**16.9**	**121.1**	**20.1**	**127.0**	**20.9**	**127.4**	**23.1**	**138.7**	**24.4**

Table 9: Staff embedded in the FPT department

The total funding of FPT is shown in Table 10.

TOTAL	2014		2015		2016		2017		2018		2019		2020	
	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Direct funding[1]	3145	41%	3158	42%	3517	47%	4496	55%	4609	56%	4614	50%	5416	53%
Research funding[2]	1034	13%	1331	18%	1214	16%	679	8%	966	12%	1039	11%	1152	11%
Contract research[3]	3514	46%	2987	40%	2589	35%	3072	38%	2674	32%	3484	38%	3493	34%
Other[4]	9	0%	-21	0%	172	2%	-74	-1%	2	0%	62	1%	105	1%
Total funding	**k€ 7703**		**k€ 7455**		**k€ 7491**		**k€ 8173**		**k€ 8252**		**k€ 9199**		**k€ 10166**	

Table 10: Total funding at level of the FPT department. All amounts in k€.

1. Direct funding by the University, obtained directly from the University, and financial compensation for educational efforts.
2. Research funding obtained in national and international scientific competition (e.g. grants from NWO, KNAW, EU/ERC, ESF).
3. Research contracts for specific research projects obtained from external organisations, such as industry, government ministries, the European Commission, and charity organisations.
4. Funds that do not fit the other categories.

RESEARCH QUALITY

Overall the high research quality of the department is commended. FPT has a broad research portfolio, but with clear connections among the different focus areas. In addition to a very high quality of research, the department has a good blend of fundamental and applied research, with some excellent examples of technological innovations and scientific impact. Examples include the new PIV technology from Prof. Scarano (used in many real-world applications, including Formula 1), the Flying-V aircraft, and wind turbine technology advances that have led to measurement efficiency gains.

The focus of scientific publication has further shifted the emphasis towards high-quality peer-reviewed journal contributions and less towards conference articles. As a result, the scientific impact of the research publications has increased.

The Committee was particularly impressed by the way in which the FPT research portfolio has pivoted and expanded to seize new opportunities in at the interfaces of flow physics and artificial intelligence (AI). TUD is uniquely well positioned to blend experimental data, simulation data and AI techniques. The MT seem well aware and executing swiftly on the opportunity. One example is the new AIFluids Lab, but there are also many other examples in the existing groups.

The FPT experimental facilities are extensive and have a reputation for being world leading. Recently four new facilities (acoustic wind tunnel, combustion test rig, hyperspectral laser lab and organic fluid flow and turbine facility) have been added. The Committee noted that the experimental data from FPT facilities are made open under TUD's Open Science initiative, but these data sets are not highly visible or easily accessible to the outside world. FPT in particular has an excellent opportunity to lead the world in curating and releasing complex flow physics data sets. There is particular demand for such data sets by the many researchers working in scientific machine learning.

Relevance to Society

Sustainability of aviation is a clear societal priority and aligns with the mission of the Faculty of AE.

Since the last review, the objectives and structure of AWEP/FTP have been changed to enhance a significant focus on sustainable aviation. There are a number of new professors, through a combination of new chairs being created, e.g. in Wind Energy, and hires to replace retirements. The focus on sustainable aviation is evident across all aspects of the FTP research portfolio, supporting green aircraft, green engines, efficient power systems, and wind energy. This focus is timely and aligns the FTP department well with industrial needs and societal priorities.

Viability

FPT is a coherent department with excellent research staff. There is the opportunity to grow further because of student interest and clean aviation/ wind energy. The growth ambitions are limited by the building and labs.

The FTP department has a successful track record when it comes to research funding. For the period from 2013-2019, the department procured a cumulative research funding of 48.2 million euros. From a funding perspective, the department has strong continued viability for the future.

During the site visit the Committee learned two reasons for the recent name change: 1) the old name was considered to be a sum-up of the activities of the department, but did not recognise the overarching theme; 2) with the new name FPT wants to stimulate collaboration between the research groups, and also with other departments.

The involvement of younger staff in strategy discussions seems mainly limited to members of the MT. The Committee encourages FTP to initiate and formalise department wide meetings where strategic planning, collaboration with other departments in and beyond AE, and HR-issues are being discussed [18]. In particular, let the younger generation fuel the minds of the decision makers.

LIST OF RECOMMENDATIONS

The Committee recommends FTP to:

[18] Initiate and formalise department wide meetings on strategic planning and collaboration.

3.3 RESEARCH DEPARTMENT CONTROL AND OPERATIONS (C&O)

Head of Department	Prof. Dr. Ir. M. Snellen (since May 2022)
Research staff 2020	18.3 Research FTE (excluding PhD)

The self-assessment report states: "The mission of the Control and Operations (C&O) department is to improve the sustainability of air transport, by enhancing the safety, efficiency and resilience of air transport operations, while reducing their environmental impact". The department's focus is to realise this mission by leveraging the potential of the digital transformation, leading to self-intelligent, adaptive and easily human-operable air transport mobility. The report adds that the axis of the research covered is both systemic (taking a 'systems-of-systems' perspective) and at the level of individual components of the air transport system.

The C&O department combines a select range of fundamental and applied research lines that aim to advance the development of models, methods, simulations and integrated tools, for:

1) more capable automatic control systems in terms of adaptability and autonomy, and more advanced human-machine interfaces to interact with them,
2) multi-objective and multidisciplinary analysis, simulation and optimisation of air transport operations, including advanced sociotechnical systemic elements, and
3) more accurate prediction of air traffic flows, the noise annoyance, emissions and corresponding air quality and climate effects.

C&O focusses mainly on the following research areas: Impact on the Environment, Air Traffic Management, Unmanned Air Vehicle Traffic

Management, Airport Operations, Airline Operations, Autonomous flight, Human operator, AI, big data and machine learning.

The themes are investigated by the three sections within the C&O department, each with their own areas of expertise: Section Control and Simulation (C&S), including Communication, Navigation & Surveillance in Air Traffic Management (CNS/ATM), Section Air Transport Operations (ATO), and Section Aircraft Noise and Climate Effects (ANCE).

The research staff is composed of 8.5 FTE scientific staff[6], 9.8 FTE post-docs and 76 PhD candidates (2020).

Table 11 shows the demonstrable research output of the C&O department.

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Refereed articles	40	43	58	68	79	92	88
Non-refereed article	1		1	1		1	1
Books			2				
Book chapters	5	4	4	2	3	2	1
PhD theses	7	3	6	9	14	12	12
Conference papers	74	75	90	92	96	80	41
TOTAL	**127**	**125**	**161**	**172**	**192**	**187**	**143**

Table 11: Total output of the C&O department

[6] Comparable with WOPI categories HGL, UHD and UD; tenured and non-tenured staff.

The composition of the research staff of C&O is shown in Table 12.

	2014		2015		2016		2017		2018		2019		2020	
	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE
Assistant professor	13.2	5.2	14.0	5.4	13.8	5.5	14.0	5.6	12.0	4.8	12.8	5.1	14.1	5.4
Associate professor	4.3	1.7	4.0	1.6	4.0	1.6	4.0	1.5	5.0	1.9	5.9	2.3	3.0	1.2
Full professor	4.0	1.5	4.0	1.5	4.8	1.6	5.0	1.5	5.0	1.5	5.3	1.5	6.8	1.9
Researchers	5.5	2.9	6.5	4.4	10.4	8.2	11.6	9.1	7.0	5.4	9.6	6.4	15.2	9.8
PhD candidate	54.2		64.6		73.3		77.3		85.4		75.5		76.3	
Total research staff	**81.1**	**11.4**	**93.1**	**13.0**	**106.3**	**16.9**	**111.9**	**17.7**	**114.4**	**13.6**	**109.1**	**15.3**	**115.3**	**18.3**

Table 12: Staff embedded in the C&O department

The total funding of C&O is shown in Table 13.

TOTAL	2014		2015		2016		2017		2018		2019		2020	
	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Direct funding[1]	3126	55%	3116	60%	3397	58%	4129	66%	4097	57%	4266	63%	4630	61%
Research funding[2]	212	4%	173	3%	196	3%	165	3%	405	6%	257	4%	388	5%
Contract research[3]	1826	32%	1519	29%	1636	28%	1758	28%	2539	35%	2121	31%	2495	33%
Other[4]	469	8%	405	8%	622	11%	204	3%	137	2%	115	2%	139	2%
Total funding	**k€ 5633**		**k€ 5212**		**k€ 5851**		**k€ 6256**		**k€ 7179**		**k€ 6758**		**k€ 7653**	

Table 13: Total funding at level of the C&O department. All amounts in k€.

1. Direct funding by the University, obtained directly from the University, and financial compensation for educational efforts.
2. Research funding obtained in national and international scientific competition (e.g. grants from NWO, KNAW, EU/ERC, ESF).
3. Research contracts for specific research projects obtained from external organisations, such as industry, government ministries, the European Commission, and charity organisations.
4. Funds that do not fit the other categories.

RESEARCH QUALITY

The department articulated a clear mission of sustainable aviation operations and control, which also aligns with the faculty mission of sustainable aerospace. The C&O Department has established strong expertise on these and related research topics. The faculty are very productive, and have a strong track record of disseminating their research at top-tier conferences and journals. The wide range of research topics – from flight vehicle control to air traffic control to airline maintenance operations – is impressive, and seen in very few other top research programmes worldwide. This breadth of expertise, complemented by collaborations with other departments and faculties both within and outside TUD, make the C&O Department one of the top ones. The Committee appreciated the lab tours, which included demonstrations at the micro-UAV scale, a flight simulator, and air traffic simulators. These tours also showed good synergies between the research and education endeavours of the C&O Department. The Committee wanted to emphasize a highlight of the lab tours, namely, the impressive advances with the neuromorphic drone control demonstrated by Prof. Dr. G.C.H.E. de Croon and his students.

RELEVANCE TO SOCIETY

The overarching mission of sustainable aviation has clear and immediate relevance to society, and is also well-aligned with the mission of the Faculty of Aerospace Engineering. The C&O mission also presents the opportunity to recruit many diverse students to the department. The existing expertise that spans the control, environmental, and operational aspects of aviation, places the department in a position to be a world-leader in this field.

VIABILITY

Overall, the Committee felt that C&O was a well-organised department. The staff in general feels involved in strategic planning and discussions. The Committee was impressed to see many collaborations with the other departments in the Aerospace faculty, as well as with other faculties taking place: Electrical Engineering, Civil Engineering, Technology, Policy and Management, Applied Physics and Mechanical Engineering. However, we recommend that the connections and collaborations with the other departments be made more clear and strategic, at least in written reports [19].

There is a good balance of research and education. In particular, the Committee was happy to hear that some full professors teach BSc-level students. The Committee also noted good synergies for C&O to use facilities (e.g. the flight simulators) in both research and educational activities.

The infrastructure and facilities – e.g. laboratory aircraft, drone testbeds, flight and air traffic control simulators, and access to airports for environmental sensing and monitoring – presents an opportunity to build a data hub around the aviation data centred on the C&O department [20].

The committee believes that relatively large number of tenure-track Assistant Professors relative to the number of Associate and Full Professors is a cause for some caution. While this imbalance is true for all departments, it appears to be particularly pronounced for the C&O Department, which has 17 Assistant Professors, 4 Associate Professors, and 7 Full Professors. That said, the criteria for tenure trackers appears to be clear, and the career path from Assistant to Associate Professor appears to be clear for the staff.

LIST OF RECOMMENDATIONS

The Committee recommends C&O to:

[19] Make the connections and collaborations with the other departments more clear and strategic;
[20] Play a leading role to become a world leading data hub for the field of Aerospace Engineering.

3.4 RESEARCH DEPARTMENT OF SPACE ENGINEERING (SPE)

Head of Department	Prof. Dr. Ir. Pieter Visser
Research staff 2020	14.2 Research FTE (excluding PhD)

The self-assessment reports that the Space Engineering department (SpE) conducts space research and education of engineers and scientists to advance the frontiers of space systems and missions, spaceflights and planetary science for the benefit of society. SpE tries to cover the complete cycle of space missions: from concept to application, and from launch to end-of-life.

According to the self-assessment report the department stimulates scientists and engineers to making access to space more affordable, to exploiting space for a better understanding of the Earth and the solar system, and to satisfying society's curiosity in the quest for extra-terrestrial life.

The department's research portfolio consists of four interconnected topics: Distributed Space Systems, Astrodynamics, and Planetary Exploration and Instrument designs (here focusing on optical instruments). Parts of the work is still very much focused on miniaturization.

The Space Engineering department (SpE) consists of the section Astrodynamics and Space Missions (AS) and the section Space Systems Engineering (SSE). A new section, Spaceborne Instrumentation, had been established in August 2021, and is under construction.

The research staff is composed of 7.8 FTE scientific staff[7], 6.4 FTE post-docs and 28 PhD candidates (2020).

Table 14 shows the demonstrable research output of the SpE department.

	2014	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Refereed articles	46	40	60	55	56	55	53
Non-refereed article			1				2
Books		1	1	3			
Book chapters	6	2	2	6		2	
PhD theses	4	2	5	2	5	6	2
Conference papers	47	29	33	40	33	27	20
TOTAL	**103**	**74**	**102**	**106**	**94**	**90**	**77**

Table 14: Total output of the SpE department

The composition of the research staff of SpE is given in Table 15.

	2014		**2015**		**2016**		**2017**		**2018**		**2019**		**2020**	
	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE
Assistant professor	8.9	3.3	8.6	3.3	9.9	3.8	10.8	4.2	12.3	4.8	12.0	4.8	12.3	4.9
Associate professor	2.3	0.8	1.8	0.7	2.0	0.8	2.0	0.8	2.3	0.9	3.0	1.1	5.0	1.8
Full professor	1.9	0.8	3.3	1.1	4.0	1.2	4.0	1.2	4.0	1.2	4.0	1.2	4.0	1.1
Researchers	5.7	4.4	6.2	4.9	7.8	6.1	9.8	7.6	10.2	7.9	9.9	7.7	8.5	6.4
PhD candidate	25.9		31.3		32.5		31.6		30.2		26.3		28.3	
Total research staff	**44.8**	**9.3**	**51.1**	**10.0**	**56.2**	**11.9**	**58.2**	**13.8**	**59.0**	**14.8**	**55.3**	**14.7**	**58.1**	**14.2**

Table 15: Staff embedded in the SpE department

[7] Comparable with WOPI categories HGL, UHD and UD; tenured and non-tenured staff.

The total funding of SpE is given in Table 16.

TOTAL	2014		2015		2016		2017		2018		2019		2020	
	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%	k€	%
Direct funding[1]	1680	57%	1681	67%	1872	59%	2504	74%	2703	72%	2865	71%	3408	76%
Research funding[2]	638	21%	333	13%	503	16%	438	13%	328	9%	359	9%	306	7%
Contract research[3]	451	15%	517	21%	505	16%	381	11%	725	19%	802	20%	672	15%
Other[4]	201	7%	-26	-1%	283	9%	61	2%	24	1%	24	1%	82	2%
Total funding	**k€ 2969**		**k€ 2505**		**k€ 3136**		**k€ 3384**		**k€ 3779**		**k€ 4050**		**k€ 4468**	

Table 16: Total funding at level of the SpE department. All amounts in k€.

1. Direct funding by the University, obtained directly from the University, and financial compensation for educational efforts.
2. Research funding obtained in national and international scientific competition (e.g. grants from NWO, KNAW, EU/ERC, ESF).
3. Research contracts for specific research projects obtained from external organisations, such as industry, government ministries, the European Commission, and charity organisations.
4. Funds that do not fit the other categories.

RESEARCH QUALITY

The overall research quality of SpE is good. If the Department would show more ambition and would redirect the scope of the research, the research quality could be further improved. The Committee feels there is ample potential for excellent research within the participating groups.

It is well recognised that SpE shifted its scope from the former focus on precise orbit determination and control to instrumentation. It is recommended that SpE brings the instrumentation activities closer to C&O. Additionally, planetary exploration, and space systems engineering are very important.

The project achievements are still few, but the project intentions are promising, e.g. the Pride instrument on JUICE, Life marker chips on the Icy Moons mission and optical space instrumentation. Overall, it is recommended here to focus the instrumentation aspect not only on

interplanetary applications but also on terrestrial applications to contribute to the overall faculty goal of sustainable aviation.

Regarding formation flying (or "Distributed Space Systems") there is apparently no awareness of competitive positions, e.g. in Würzburg (3D formations with 4 satellites and RF inter-satellite communication). The Committee recommends to formulate new, more challenging goals. Formation flying of two satellites is really minimalistic and nothing exceptional. It is standard in industry (GRACE, GFO, TESAT/DLR ISL mission etc.).

The Committee thinks that SpE could dare a bigger mission (min. 6U, better 12U/16U cube) to explore the real challenges of attitude control, substantial payload technology, pointing precisions, science data onboard storage and downlink etc. This also for the sake of flying a substantial payload and good education on systems engineering.

Substantial technical topics are missing (instrument designs optical, radar, telecom satellites, laser payloads). During the first result presentation it was mentioned that SpE is intending to build a small constellation of CubeSats with miniaturized versions of the S5P TROPOMI instrument. This demonstrates a certain trivialized perception.

The Committee also was surprised about a PhD to state that TUD is intending to build laser-link terminals, which means to chase up/ build replicas of things that DLR (Osiris), TESAT and Mynaric already have. This is no innovation but replicating industry products, and the complexity of developing such terminals both on material as well as on control/SW side seems completely underestimated.

Instead of re-building laser space and ground terminals which are available as commercial products, the Committee recommends using an OSIRIS-4 of DLR (or similar terminal) for science data downlink of the satellite substantial instrument requested above and to procure a laser ground-station (DLR?). SpE should focus on the instrument, the science

data storage onboard and the satellite system/modes/cmd/ ctrl. – also, to again link the development/research to the overall goal of sustainable aerospace [21].

The Committee was not impressed by the research output. The number of publications has decreased since its high tides in 2014/2017 by approximately 25%. With a research staff of 14.2 FTE plus 28 PhDs the department has approximately 42 publishing persons as of 2020. A result of 77 publications overall makes a bit less than 2 publications per researcher in average which is still ok, but by far topped by TUD's other Aerospace departments as well as by competing departments of other universities.

What is particularly amazing is the lack of book chapter publications in 2018/2020. Since typically even best paper awards of conference papers lead to conference publication book chapter from Springer, Wileys etc. This inversely demonstrates the limited relevance of SpE publications. Over the entire 7 years 5 books have been published in the entire department. This is ok, but definitely not an outstanding track of research results.

RELEVANCE TO SOCIETY

The work of SpE is very relevant and SpE has significant potential to make even more impact in the future. The SpE department had an influx of about 90 MSc students in the years 2020 and 2021, resulting in a total of above 300 active MSc students, which is remarkable and shows the interest of students in space engineering. This alone demonstrates the relevance of SpE to society.

A word of care should me made here: students do not learn substantial systems engineering when just using toys: Pocket-Cubes are not suitable for serious education, since the real challenges of satellite engineering

are neglected, e.g. instrument alignments, energy budgeting, pointings, mode/failure management, redundancies and last but extremely important - substantial flight SW.

Concerning research impact, the Committee suggests to focus on bigger SmallSats/CubeSats. Furthermore, it is recommended to build instruments and to host them in SmallSats [22]. Not many competing Universities build instruments. SpE is encouraged to focus on the instruments, the science data storage onboard and the satellite system/modes/cmd/ctrl, flight SW, again to hook the payload instrument observation data to the overall goal of the Faculty – sustainable aerospace [23]. The science data hosting/postprocessing on ground then automatically opens up perspectives for open data applications, AI data processing etc. and thus cross links to other disciplines and increases relevance to society.

It is well recognised that the first real instrumentation from the department is still outstanding since the branch is still new. A concrete concept from such an EO instrument with realistic/moderate complexity was not presented and is still outstanding.

VIABILITY

From 2014 to 2020 a continuous increase in department staff can be monitored which is a good sign of continuous growth and evolution. With growth numbers of 40% over recent years, 9 extra staff, and increasing PhD-numbers, SpE is becoming an entity on its own instead of mere servicing other sections. However in 2020 the headcount for full professor positions still was only at 1.1 FTEs research capacity. With the broadening of the scientific scope of the department it is recommended to increase this.

300 Students in the master space track is remarkable and shows the interest in space of the young generation. The sheer number may be a

cause for both opportunity and threat, e.g. with relation to resources. On the threat side: the educational mission seems to constrain the research. The Faculty would benefit from more exposure and engagement with world class external research. Also, more resources are needed to expand the programme. On the opportunity-side: SpE is a big growth area, and especially with the planetary and instrumentations there are many opportunities for future growth.

SpE is doing a lot better than the self-assessment report shows. In Space it is not yet a leading department at TUD, but its development is promising.

The Committee thinks diversifying the research area to instrumentation and planetary activities is the right track. Also, the Committee is happy to see diversification in the direction of instrumentation, away from the pure precise orbit and attitude control. This is an impressive job, that gives also opportunity for broader collaboration with other departments, industry and other universities.

The Committee is surprised to see that infrastructure is missing in the report. SpE is recently defining and building new labs. Facilities are improving but still are far behind what is available at competing universities in and outside Europe.

The intra-section collaboration is still underdeveloped, and also SpE still seems a bit distracted from the department. Some improvements could arise from payload instrument Earth observation science data.

Overall, for SpE the Committee recommends to focus on space research that supports the sustainability mission; designing a substantial satellite mission that advances the research combining all the disciplines and aligned with the Faculty strategy. Not for the sake of education but for catching up on the science side.

The overall viability of the Space department is on track. It will significantly profit further from a substantial satellite mission as was suggested above.

LIST OF RECOMMENDATIONS

The Committee recommends SpE to:

[21] Focus on the instruments, the science data storage onboard and the satellite system/modes/cmd/ctrl, flight SW;
[22] Dare a bigger mission. Generate more impact (in both academia and commercial) with bigger SmallSats/ CubeSats. Build instruments and host them in SmallSats;
[23] Hook the payload instrument observation data to the overall goal of the Faculty – sustainable aerospace.

CONCLUSION

AE is a large Faculty with a wide scope of aerospace research topics. The depth and variety of researched topics and achieved professional level make TUD an attractive and good place to be for researchers as well as for students and PhD candidates.

The scientific/engineering recognition of the four departments is still differing, but especially in SpE slowly ramping up. The Strategic goal of "Sustainable Aerospace" is formulated and envisaged. The Committee is aware that the achievement of strategic goals needs some patience. The Strategies for Open Data and Data Pools for big data / AI analysis are identified and envisaged to be treated now as shorter term tactical goals.

With a better caring for the data that could be generated, the Faculty of AE could become an aviation data hub to the world, and generate much more (societal and scientific) impact.

With these positive perspective bullets the Committee is confident about the Faculty having a successful future.

APPENDIX A CURRICULA VITAE OF THE COMMITTEE MEMBERS

Professor C.J. (Hans) van Duijn, Committee Chair, obtained a MSc in Applied Physics from Eindhoven University of Technology and a PhD in Mathematics from Leiden University. He then did a postdoc at the School of Mathematics of the University of Minnesota. Returning to the Netherlands he worked as a project engineer for Delft Soil Mechanics Laboratory, as an associate professor at the Department of Mathematics of Delft University of Technology (later combined with a professorship at Leiden University) and then as a group leader at the Centre for Mathematics and Computer Science (CWI, Amsterdam) combined with a professorship at Delft. In 2000 he moved back to Eindhoven University of Technology to hold a chair in Applied Analysis. His field is nonlinear partial differential equations with applications to flows in porous media. Recently he works on problems from soil mechanics, with particular interest in homogenization, and on multi-phase problems with hysteresis. In 2005 until his retirement in 2015 he was Rector Magnificus of Eindhoven University of Technology. Currently he chairs the Sectorplancommissie Beta en Techniek, the NWO Permanent Committee for Large Scale Scientific Infrastructure and the board of the Dutch Research School of Fluid Mechanics (JM Burgers Centre). His is also a member of the supervisory board of Erasmus University Rotterdam. In 1996 he was awarded the Leermeesterprijs of Delft University of Technology and in 1998 the Max Planck Award for International Cooperation.

Professor. H. (Hamsa) Balakrishnan is the William E. Leonhard (1940) Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology (MIT). She previously served as the Associate Department Head of Aeronautics and Astronautics at MIT. She received her PhD from Stanford University, and a B.Tech. from

the Indian Institute of Technology Madras. Prior to joining MIT, she worked at NASA Ames Research Center. Her research is in the design, analysis, and implementation of control and optimization algorithms for cyber-physical infrastructures, with an emphasis on air transportation. She is the co-founder and chief scientist of Lumo, a Boston-based travel startup. Prof. Balakrishnan is an Associate Fellow of the American Institute of Aeronautics and Astronautics (AIAA), the recipient of an NSF CAREER Award in 2008, the CNA Award for Operational Analysis in 2012, the AIAA Lawrence Sperry Award in 2012, the American Automatic Control Council's Donald P. Eckman Award in 2014, the MIT AIAA Undergrad Advising (2014) and Undergraduate Teaching (2019) Awards, and several best paper awards.

Professor J. (Jens) Eickhoff graduated as Diplomingenieur for Aerospace Engineering from Universität Stuttgart in 1989 after which he started work at former Dornier System GmbH (Airbus Defence and Space), Friedrichshafen, Germany. He did his PhD from 1990-1995 at TU Hamburg-Harburg in Process Engineering as sideline activity. At Dornier/Astrium/Airbus he was responsible for the development of diverse system simulators. He was simulation infrastructure lead for ESA, DLR and EU programs CryoSat, GOCE, Aeolus, TerraSAR , Galileo IOV, then was functional verification lead for Sentinel 2A and today is responsible for Innovation and New-Space Programs at Airbus DS, Friedrichshafen.
Since 2003 Jens Eickhoff is lecturing at Universität Stuttgart, System Simulation, Satellite Verification, Onboard Computers, Onboard Software and Satellite Operations. In 2011 he was awarded an Honorary Professorship. He and his PhDs developed the functional Avionics Platform of the University Satellite “Flying Laptop”, which he and his Airbus + SME team meanwhile industrialized to the “Flexible LEO Platform”. He is Author and Editor of at present 5 Books, affiliated multiple patents and is regular guest lecturer at international space

institutions/ universities such as INPE, IIST, JPL, GISTDA, PhilSA, SANSA, TU Munich, TU Delft, Caltech, MIT, University of Cape Town, Chulalongkorn University. His interests are onboard core avionics, Ethernet payload applications and onboard AI based image processing.

Dr.ir. W.J.B. (Wouter) Grouve is Assistant Professor of thermoplastic composites in the Production Technology group of the Faculty of Engineering Technology at the University of Twente. He graduated with honours from the University of Twente in 2006, and later received his PhD degree in 2012 with honours from the same university on the topic of laser-assisted fibre placement for thermoplastic composites. Subsequently, Wouter Grouve spent five years in industry as a senior research associate at the ThermoPlastic composite Research Center (TPRC), where he coordinated a large collaborative research program between industry and academia. In 2018, he moved back to the University of Twente to take up his current role as an Assistant Professor. His research focuses on the development of (simulation) tools and technologies to enable first-time-right manufacturing of thermoplastic composite aircraft structures. Dr.ir. Grouve is the recipient of the ESAFORM PhD Prize for Industrial Research (2014), the IOM3 Composite Award (2014), as well as the best Master Thesis award of the UT Mechanical Engineering program. He is the chairman of the Faculty Council and a member of the Technical Advisory Board of TPRC.

Ir. C.J.M. (Conrad) Hessels is a PhD candidate at Eindhoven University of Technology (TU/e), within the research group of power and flow, part of the department of mechanical engineering. His PhD is about the regeneration of iron powder as part of the metal energy carrier cycle. In this cycle iron powder is used as dense energy carrier by cyclic combustion and reduction. His expertise is on (1) iron-oxide – hydrogen reaction kinetics; (2) particle-gas flow behaviour; (3) Sintering behaviour of ferrous particles; (4) microstructural analysis of ferrous powder. He obtained his bachelor's degree in mechanical engineering at TU/e in 2015. Afterwards he started his masters in the group of power and flow. He did his internship at the Volvo Car Corporation in

Gothenburg, Sweden, working on post-processing of metal and optical petrol engine test data. He subsequently did his master's thesis on using Raman spectroscopy for quantitative analysis of non-premixed flames. His master thesis was awarded the TU/e Mechanical Engineering MSc Thesis Award 2018 as well as the 2nd prize of the "KHMW Nederlandse Gasindustrie Prijzen".He is a board member of section Mechanics of the Royal Dutch Society of Engineers (KIVI).

Professor K. (Karen) E. Willcox is Director of the Oden Institute for Computational Engineering and Sciences, Associate Vice President for Research, and Professor of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin. She is also External Professor at the Santa Fe Institute. At UT, she holds the W. A. "Tex" Moncrief, Jr. Chair in Simulation-Based Engineering and Sciences and the Peter O'Donnell, Jr. Centennial Chair in Computing Systems. Before joining the Oden Institute in 2018, she spent 17 years as a professor at the Massachusetts Institute of Technology, where she served as the founding Co-Director of the MIT Center for Computational Engineering and the Associate Head of the MIT Department of Aeronautics and Astronautics. Prior to joining the MIT faculty, she worked at Boeing Phantom Works with the Blended-Wing-Body aircraft design group. Willcox has co-authored more than 130 papers in peer-reviewed journals and advised more than 60 graduate students. She is the recipient of a SIAM SIGEST paper award, three AIAA best paper awards, and several awards for both leadership and teaching. In 2017 she was appointed Member of the New Zealand Order of Merit (MNZM) for services to aerospace engineering and education. She is a Fellow of the Society for Industrial and Applied Mathematics (SIAM) and a Fellow of the American Institute of Aeronautics and Astronautics (AIAA). In 2022 she was elected to the U.S. National Academy of Engineering (NAE).

APPENDIX B SITE VISIT PROGRAMME

DAY 0 – Tuesday June 7, 2022		
Time/place	Activity	Participants
17.30	Arrival of Committee and welcome	Committee + Rector Prof.dr.ir. T.H.J.J. van der Hagen
18.00 – 21.30	Working diner: kick-off and preparation of interviews	Committee (private)

DAY 1 – Wednesday June 8, 2022		
Time/place	Activity / Assessors	Participants
8.30 – 9.00	Preparation of interviews	Committee (private)
9.00 – 10.00	Interview Management Team [Start with a six minutes presentation]	Prof.dr. H.G.C. Werij (Dean) Prof.dr.ir. R. Benedictus (ASM) Prof.dr.ir. J.M. Hoekstra (CO) Prof.dr.ir. L.L.M. Veldhuis (AWEP, since May 2022 Flow Physics and Technology, FPT) Prof.dr.ir. P.N.A.M. Visser (SpE)
10.00 – 10.15	Reflection	Committee (private)
10.15 – 10.45	Interview Rector TU Delft	Prof.dr.ir. T.H.J.J. van der Hagen
10.45 – 11.00	Reflection	Committee (private)
11.00 – 11.45	Interview MT Department Space Engineering [Start with a six minutes presentation]	Prof.dr.ir. P.N.A.M. Visser (AS, chair) Prof.dr. L.L.A. Vermeersen (AS subsection PE) Dr. J. Guo (SSE) Dr. J.J.D. Loicq (Space Instrumentation, new section since August 2021, SI)
11.45 – 12.00	Reflection / Break	Committee (private)
12.00 – 13.00	Lab Tour [including poster presentations] Space Engineering	M.S, Uludag(SSE) Dr.ir. B.C. Root (AS)

13.00 – 13.45	Lunch with PhD students	Ir. G. van Helden (SSE) Ir. T-M. Bründl (AS) Ir. M.S. Fayolle-Chambe (AS) Ir. R. van Duivenvoorden (FPP) Ir. L. Laguarda Sanchez (AERO) Ir. D (Deepali) Singh (WE) Ir. L. J. Kootte (ASCM) Ir. C. M. de Zeeuw (SIC) Ir. S. Gomarasca (AMT) Ir. F (Flavio) Quadros (ANCE) Ir. M. (Marta) Ribeiro (CS) Ir. J. (Juseong) Lee (ATO) Ir. S.di Mascio (SpE) Ir. J.Bulut (FPT) Ir. B.H.A.H.Tijs (ASM)
13.45 – 14.00	Reflection	Committee (private)
14.00 – 14.20	Interview Tenure Trackers Space Engineering	Dr.ir. R. Saathof (SSE) Dr. C. Siemes (AS) Dr.ir. B.C. Root (PE) Dr. B.V.S. Jyoti (SSE) Dr.ir.J.G. De Teixeira da Encarnacao (AS)
14.20 – 14.30	Reflection	Committee (private)
14.30 – 14.50	Interview Tenured Staff Space Engineering	Dr. A. Menicucci (SSE) Dr. S.M. Cazaux (AS) Dr.ir. D. Dirkx (PE) Dr.ir. M.J. Heiligers (AS)
14.50 – 15.00	Reflection	Committee (private)
15.00 – 15.45	Interview MT Department Control and Operations [Start with a six minutes presentation]	Prof.dr.ir. J.M. Hoekstra (CO, Chair till June 2022) Prof.dr.ir. M. Snellen, CO, Chair since June 2022) Prof.dr.G.C.H.E. de Croon (CS) Dr.ir. M.M. van Paassen (CS) Prof.dr. D.G.Simons (ANCE) Dr.B.F. Lopes Dos Santos (ATO)

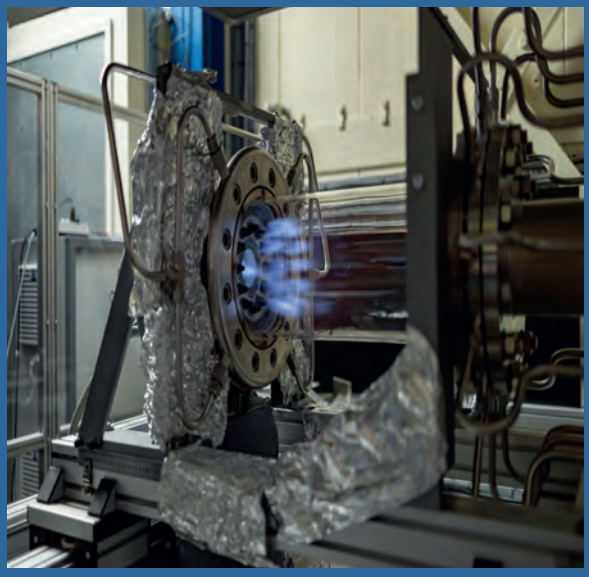
15.45 – 16.00	Reflection / Break	Committee (private)
16.00 – 16.20	Interview Tenure Trackers Control and Operations and	Dr. F. Yin (ANCE) Dr. A. Jamshidnejad (CS) Dr.ir. E.J.J. Smeur (CS) Dr.ir. S. Hamaza (CS)
16.20 – 16.30	Reflection	Committee (private)
16.30 – 16.50	Interview Tenured Staff Control and Operations	Dr. O.A. Sharpanskykh (ATO) Dr.ir. C.C. de Visser (CS) Dr. M.D. Pavel (CS) Dr.ir. J. Ellerbroek (CS)
16.50 – 17.00	Reflection	Committee (private)
17.00 – 18.00	Lab Tour Control and Operations	Prod.dr.ir. J.M. Hoekstra, ir. T.J. Mulder Prof.dr.G.C.H.E. de Croon (CS) Ir. A. Altena (ANCE) Dr.ir. M.M. van Paassen (CS) Ir. O. Stroosma (CS)
18.00	Refreshing at hotel	Committee (private)
19.30 RESTAURANT Le Vieux Jean	Working dinner: discussing and writing preliminary judgments	Committee (private)
21.30	Closure	

DAY 2 – Thursday June 9, 2022		
Time	Activity / Assessors	Participants
08.30 – 9.00	Preparation of interviews	Committee (private)
9.00 – 9.45	Interview MT Department Flow Physics and Technology (FPT) [Start with a six minutes presentation]	Prof.dr.ir. L.L.M. Veldhuis, (FPT, Chair) Prof.dr. F. Scarano, (AERO) Prof.dr. S. Hickel (AERO) Prof.dr. D.A. von Terzi (WE) Prof.dr.ir. C.J. Simão Ferreira (WE) Prof.dr.ir. P. Colonna (FPP) Prof.dr. S.J. Watson (WE)
9.45 – 10.00	Reflection	Committee (private)
10.00 – 10.20	Interview Tenure Trackers Flow Physics and Technology (FPT)	Dr.ir. T. Sinnige (FPP) Dr. D. Modesti (AERO) Dr.ir. D.A.M. de Tavernier (WE) Dr. N.A.K. Doan (AERO) Dr. D. Zappala (AERO)

10.20 – 10.30	Reflection	Committee (private)
10.30 – 11.00	Interview Diversity and Inclusion Office - Prof. Karen Willcox - Prof. Jens Eickhof	Dr.ir. A.C. Vire Dr.ir. S. Teixeira de Freitas
11.00 – 11.15	Reflection / Break	Committee (private)
11.15 – 11.35	Interview Tenured Staff Flow Physics and Technology (FPT) and	Prof.dr. A. Gangoli Rao (FPP) Dr. R.P. Dwight (AERO) Dr. D. Ragni (WE) Dr.ir. A.C. Viré (WE) Dr. M. Pini ((FPP)
11.35 – 11.45	Reflection	Committee (private)
11.45 – 12.45	Lab Tour FPT [including poster presentations]	Dr.ir. F.F.J. Schrijer (AERO)
12.45 – 13.30	Lunch with postdocs	Postdocs: Dr. Ir. Theo Michelis (FPT) Dr. Nan Yue (ASM) Dr. Matthew Yetudenko (CO)
13.30 – 14.15	Interview MT Department Aerospace Structures and Materials [Start with a six minutes presentation]	Prof.dr.ir. R. Benedictus (ASM, Chair) Dr.ir. R. de Breuker (ASCM) Dr.ir. R.C. Alderliesten (SIC) Dr. S. J. Garcia Espallargas (NOVAM) Prof. C.A. Dransfeld (AMT
14.15 – 14.30	Reflection	Committee (private)
14.30 – 14.50	Interview Tenure Trackers Aerospace Structures and Materials	Dr. J.J.E. Teuwen (AMT) Dr.ir. J.A. Pascoe (SIC) Dr. X. Wang (ASCM) Dr.ing. S. G. P. Castro (ASCM) Dr. B. Caglar (AMT)
14.50 – 15.00	Reflection	Committee (private)
15.00 – 15.20	Interview Tenured Staff Aerospace Structures and Materials	Dr. D. Zarouchas (SIC) Dr. C. D. Rans (SIC) Dr. K. Masania (AMT) Dr.Ir. S. Teixeira de Freitas (SIC)
15.20 – 15.30	Reflection / Break	Committee (private)
15.30 – 16.30	Lab Tour Aerospace Structures and Materials	Dr.ir. B. van Schooten

16.30 – 17.00	Interview Scientific Career Committee	Prof.dr. F. Scarano Prof.dr.ir. P.N.A.M. Visser
17.00 – 17.15	Reflection	Committee (private)
17.15 – 17.45	Interview Graduate School	Prof.dr. P. Colonna Prof.dr.ir. J.M. Hoekstra
17.45 – 18.00	Reflection	Committee (private)
18.00	Refreshing at hotel	Committee (private)
19.30 Hotel	Working dinner: discussing and writing preliminary judgments	Committee (private)
21.30	Closure	

DAY 3 – Friday June 10, 2022		
Time	Activity / Assessors	Participants
08.30 – 9.30	Summarizing findings and first conclusions	Committee (private)
9.30 – 10.00	Concluding meeting with management team AE	Prof.dr. H.G.C. Werij (dean) Prof.dr.ir. R. Benedictus (ASM) Prof.dr.ir. L.L.M. Veldhuis (FPT) Prof.dr.ir. P.N.A.M. Visser (SpE) Prof.dr.ir. J.M. Hoekstra (CO, Chair till June 2022) Prof.dr.ir. M. Snellen, CO, Chair since June 2022)
10.00 – 12.00	Discussing and writing preliminary judgments (including Break)	Committee (private)
12.00 – 12.30	Oral presentation on first impression by Committee	Committee All faculty members invited
12.30 – 13.00	Closure	Refreshments/lunch with Committee and MT



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