

2/2017

Rigsrevisionen's report on

**the basis for decision prepared  
by the Danish Ministry of Defence  
concerning procurement of 27  
F-35 combat aircraft**

submitted to the Public Accounts Committee

STATSREVISORERNE  
RIGSREVISIONEN



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Rigsrevisionen initiated this study and therefore submits this report to the Public Accounts Committee under section 17(2) of the Auditor General's Act; see Consolidation Act No. 101 of 19 January 2012.

Rigsrevisionen has audited the accounts according to section 2(1)(i); see section 3 of the Auditor General's Act.

The report relates to the Danish Appropriation Act, section 12. The Ministry of Defence.

In the period during which the study was carried out, the ministries were headed by the following ministers:

Nick Hækkerup: October 2011 - August 2013

Nicolai Wammen: August 2013 - June 2015

Carl Holst: June 2015 - September 2015

Peter Christensen: September 2015 - November 2016

Claus Hjort Frederiksen: November 2016 -

A draft report has been submitted to the Ministry of Defence, and its comments are reflected in the report.

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# 1. Introduction and conclusion

## 1.1. PURPOSE AND CONCLUSION

1. This report concerns the basis for decision prepared by the Danish Ministry of Defence – and completed in 2016 – concerning procurement of new combat aircraft for the Danish Defence. In the basis for decision, the Ministry of Defence concluded that the procurement of 27 F-35 combat aircraft would meet the level of ambition set out for the new combat aircraft. The ministry estimates the procurement and operational costs of the combat aircraft at approximately DKK 66 billion over the next 30 years. This makes it one of government's largest procurements to date. The basis for decision prepared by the Ministry of Defence led to a political agreement, entered in June 2016, to purchase 27 F-35 combat aircraft – also known as Joint Strike Fighters.

2. The political agreement highlights several risks related to the ongoing development of the F-35 combat aircraft and mentions that the calculations presented in the basis for decision rest on various assumptions concerning optimisation and efficiency.

3. The Ministry of Defence is expected to submit a document to the Finance Committee in November 2017 asking for approval of the procurement. The basis for decision will be incorporated in the request for approval along with supplementary details and a specification of the scope of the final procurement made by the Ministry of Defence. It follows that Rigsrevisionen's study was carried out before the Danish parliament had made a final decision on the procurement of the new combat aircraft. Rigsrevisionen has reviewed the basis for decision to provide the Danish parliament with a sound basis for its decision.

### PROCUREMENT OF NEW COMBAT AIRCRAFT

The agreement to procure new combat aircraft was entered in June 2016 between the following political parties:

- The government (the Liberal Party)
- The Social Democratic Party
- The Danish People's Party
- The Liberal Alliance
- The Danish Social Liberal party.



*F-35 combat aircraft.*

Photo: CPC Collection/Alamy Stock Photo

4. The purpose of the study is to assess whether the Ministry of Defence has provided an adequate basis for the decision to procure 27 F-35 combat aircraft. The report answers the following questions:

- Has the Ministry of Defence carried out an adequate assessment of whether the procurement of 27 F-35 combat aircraft will meet the level of ambition set out for Danish combat aircraft?
- Has the Ministry of Defence applied an appropriate model for the analysis of the life-cycle costs of procuring 27 F-35 combat aircraft?

Rigsrevisionen initiated the study in December 2016.

## CONCLUSION

The political agreement to procure new combat aircraft was made on the basis for decision provided by the Ministry of Defence. It is Rigsrevisionen's assessment that the basis for decision is, generally, underpinned by thorough analyses and calculations. However, the study shows that the Ministry of Defence has not provided evidence for a number of key assumptions underlying the calculations, nor has it reflected the uncertainty associated with the assumptions. It is Rigsrevisionen's assessment that there is a higher risk – than indicated in the basis for the decision – that the Danish Defence will be unable to perform all the agreed tasks with the 27 F-35 combat aircraft.

Rigsrevisionen's study shows that the calculation of the necessary number of flight hours is based on assumptions concerning synergy and the pilots' working conditions. However, these assumptions are not sufficiently evidenced nor is the possibility that they do not hold adequately reflected. The study also shows that the Ministry of Defence's calculation of the total number of flight hours for the 27 F-35s does not reflect potential shortcomings of the assumptions concerning average number of flight hours per year or the availability rate of the aircraft. Therefore, there is a risk that the requirement for flight hours has been underestimated, and the total number of flight hours overestimated. The basis for decision should have highlighted the risk related to the necessary number of flight hours and the total number of flight hours, since both aspects have an impact on the ability of the 27 F-35 combat aircraft to deliver all the required tasks.

Furthermore, Rigsrevisionen's study shows that the Ministry of Defence has estimated the life-cycle costs for the 27 F-35 combat aircraft at approximately DKK 66 billion over 30 years. Overall, the Ministry of Defence has employed an adequate model for calculating the life-cycle costs, but the ministry has not adequately reflected all the risks associated with the underlying assumptions concerning, for instance, synergy and the pilots' working conditions. Therefore, the ministry may have underestimated the costs allocated to cover risks, which may increase the estimated life-cycle costs. The Ministry of Defence has informed Rigsrevisionen that if these risks materialise, it would expect the capabilities of the Danish Defence to deliver the expected tasks to be affected first.

Based on the results of the study, Rigsrevisionen finds that the Ministry of Defence should improve the Danish parliament's basis for decision in connection with the submission of the request for approval of the procurement to the Finance Committee by:

- Accounting for the risk associated with the key assumptions, including the inherent risk that the Danish Defence cannot deliver all the expected tasks with the 27 F-35 combat aircraft.
- Updating the estimated costs of covering risks and more clearly reflecting the risk associated with the estimated total life-cycle costs.

### PORTFOLIO OF TASKS

In this report, the portfolio of tasks refers to the tasks that the combat aircraft are required to perform in accordance with the basis for decision.

### SYNERGY

Synergy is the reduction in flight hours that can be achieved when flight hours in connection with missions can replace training hours. In assuming that pilots are trained while flying international operations, the requirement for flight hours needed for training can be reduced. The synergy depends on the type, complexity and versatility of the performed tasks. Training obtained during one type of mission does not necessarily make up for training.

## 1.2. BACKGROUND

### PROCUREMENT OF F-16 COMBAT AIRCRAFT

In 1975, Denmark entered into an agreement to purchase 58 F-16 combat aircraft, which were later supplemented with another 19 F-16 combat aircraft. The fleet currently consists of 44 F-16 combat aircraft, 30 of which are operational.

5. The Danish Defence currently has a fleet of 44 F-16 combat aircraft, which by 2020 will have been operational for approximately 40 years. The Ministry of Defence estimates that the continued use of the F-16 combat aircraft will pose considerable operational, technical and financial challenges. For this reason, they are to be replaced with new combat aircraft.

### The political agreement to purchase new combat aircraft

6. After repeated postponement of the decision to purchase new combat aircraft, a number of parties made a political agreement, in June 2016, to purchase 27 F-35 combat aircraft. Box 1 provides a more detailed description of the F-35 combat aircraft and the countries that have decided to acquire it.

#### BOX 1

### F-35 COMBAT AIRCRAFT

The F-35 is a US-produced combat aircraft. Three variants of the aircraft are being developed, and Denmark has elected to purchase the conventional variant (F-35A) that can be flown from ordinary take-off and landing strips.

The aircraft is being developed jointly between the chief manufacturer, Lockheed Martin, and the Joint Program Office of the US Department of Defense as well as eight other partner countries from the international Joint Strike Fighter Program (the JSF Program): the UK, Italy, the Netherlands, Turkey, Australia, Norway, Canada and Denmark. The aircraft is expected to be ordered by the USA (2,443 aircraft), the UK (138 aircraft), Australia (100 aircraft), the Netherlands (37 aircraft), Norway (52 aircraft), Israel (50 aircraft), Italy (90 aircraft), South Korea (40 aircraft), Turkey (100 aircraft) and Japan (42 aircraft). Canada has not yet decided on its purchase of combat aircraft. The combat aircraft's first flight was in 2006, and as of 1 January 2017, 200 aircraft have been produced. The first F-35 combat aircraft have been delivered to the USA, Italy, Australia, Norway, the Netherlands and Japan. The USA stationed the first F-35 combat aircraft in Europe in April 2017.

Source: Rigsrevisionen on the basis of information from the Ministry of Defence and the JSF Program.

7. According to the political agreement, the parties involved agreed to procure a total of 27 F-35 combat aircraft. The aircraft are expected to be delivered and phased-in during the period from 2021 to 2026. The first F-35 combat aircraft are to be used to train Danish pilots in the USA, while the next are required to start performing some tasks in 2022 and take over full task performance in 2027. The F-16 combat aircraft will be phased out gradually until 2024. In the period from 2022 to 2024, Danish combat aircraft will be unable to take part in international operations, and in 2025 and 2026 they will only be able to make a limited contribution to international operations.

According to the political agreement, the aircraft are to be based at Skrydstrup Airbase. The agreement also establishes that Denmark is to exploit the opportunity to benefit from Smart Defence (under the NATO umbrella, for instance), meaning that Denmark should cooperate with partner countries; and from the economies of scale that the international F-35 Joint Strike Fighter Program (the JSF Program) affords in relation to aircraft operations and maintenance. As far as the financing of the combat aircraft is concerned, the agreement states that the procurement of the combat aircraft is to be financed by the Ministry of Defence within the ministry's expected budgetary framework during the procurement and operational period.

### The basis for decision

8. Box 2 contains an extract from a statement made by the former Minister for Defence during a hearing in the Danish parliament on the procurement of combat aircraft.

#### BOX 2

##### EXTRACT FROM STATEMENT BY THEN-MINISTER FOR DEFENCE

'The government recommends that 27 F-35 combat aircraft be procured so that in future combat aircraft can be deployed in international operations and perform national tasks in Danish air space. The procurement of new combat aircraft will enable the present portfolio of tasks to be performed in future. The government's recommendation for the acquisition of 27 F-35 is partly based on the assumption that a number of optimisation measures can be implemented to reduce the number of aircraft needed. It is the government's opinion that we should not purchase more aircraft than are strictly necessary to perform the tasks.'

Source: Statement by the Minister for Defence during the Defence Committee hearing about new combat aircraft on 25 May 2016.

9. The framework of the basis for a decision to purchase new combat aircraft was the level of ambition set out in the defence agreement for 2013-2017. The agreement states that the Danish Defence is required to maintain flexible, deployment-ready combat aircraft that are deployable at short notice for national and international tasks. In the basis for decision, the Ministry of Defence has operationalised the level of ambition based on NATO standards, among other things. Box 3 describes the tasks required to be performed in accordance with the basis for decision.

#### LEVEL OF AMBITION

The level of ambition is the politically agreed tasks established in the *Danish Defence Agreement 2013-2017*. According to the agreement, the Danish Defence must have a capacity that enables it to participate in a wide variety of international missions while also performing its national tasks.



## BOX 3

**TASKS REQUIRED IN ACCORDANCE WITH THE BASIS FOR DECISION**

**Enforcement of national sovereignty:** permanent, 24-hour quick reaction alert capability of two combat aircraft + standby aircraft deployable at very short notice.

**Other national tasks:** for example, supporting other authorities such as the police.

**International operations:** a combat aircraft contribution of four combat aircraft + standby aircraft on high readiness that can be deployed for international operations and NATO's collective defence tasks at short notice for up to 12 months every three years.

**Air policing:** a periodic contribution of two combat aircraft + standby aircraft for NATO air policing missions, that is, air policing in NATO countries without their own combat aircraft for quick reaction alert.

In addition, the Ministry of Defence needs combat aircraft for instructing and training pilots, and other combat aircraft will be out of service for regular maintenance. When the phasing-in period at end-2026 has concluded, a total of five F-35 combat aircraft will be based in the USA, where they will be used for training purposes.

Source: Rigsrevisionen on the basis of the Ministry of Defence's basis for decision.

Taking the portfolio of tasks as its starting point, the Ministry of Defence has prepared a basis for decision in which it assesses which and how many combat aircraft the Danish Defence needs. The basis for decision led to the selection of the F-35 as the new combat aircraft.

**THREE-YEAR CYCLE**

The three-year cycle means that, when operating at maximum capacity, the Ministry of Defence plans to carry out the following tasks over a three-year period:

- Year 1: international operations
- Year 2: air policing
- Year 3: neither international operations nor air policing.

10. In the basis for decision, the Ministry of Defence estimated the number of flight hours and combat aircraft needed to perform the required tasks in a three-year cycle. This means, among other things, that the Ministry has based its calculation on the assumption that, every third year, the Danish Defence must be able to perform international operations entailing 12 consecutive months of deployment while securing a national quick reaction alert capability as well as instructional and training capacity. The Danish Defence will require the highest number of aircraft in those years, and the combat aircraft fleet would therefore during such periods be operating at maximum capacity.

The Ministry of Defence has stated that such a situation has not yet arisen. The ministry therefore made the assessment that the Danish Defence is unlikely to experience a situation in which it is operating at maximum capacity, and that the calculation of number of combat aircraft needed thus has an in-built element of robustness. According to the ministry, the estimate allows for a certain degree of uncertainty.

In this regard, Rigsrevisionen notes that the basis for decision is based on the Defence's ability to perform the required tasks in a three-year cycle, including periods that entail operating at maximum capacity, and that the Ministry of Defence has dimensioned capacity accordingly. Furthermore, the basis for decision does not indicate that there is an in-built robustness that makes allowance for the uncertainty. For this reason, Rigsrevisionen has based its study on the premise that the ministry is required to perform the portfolio of tasks in the basis for decision.

11. Figure 1 shows a timeline covering the process of preparing the basis for decision until a request for approval of the procurement is submitted to the Finance Committee.

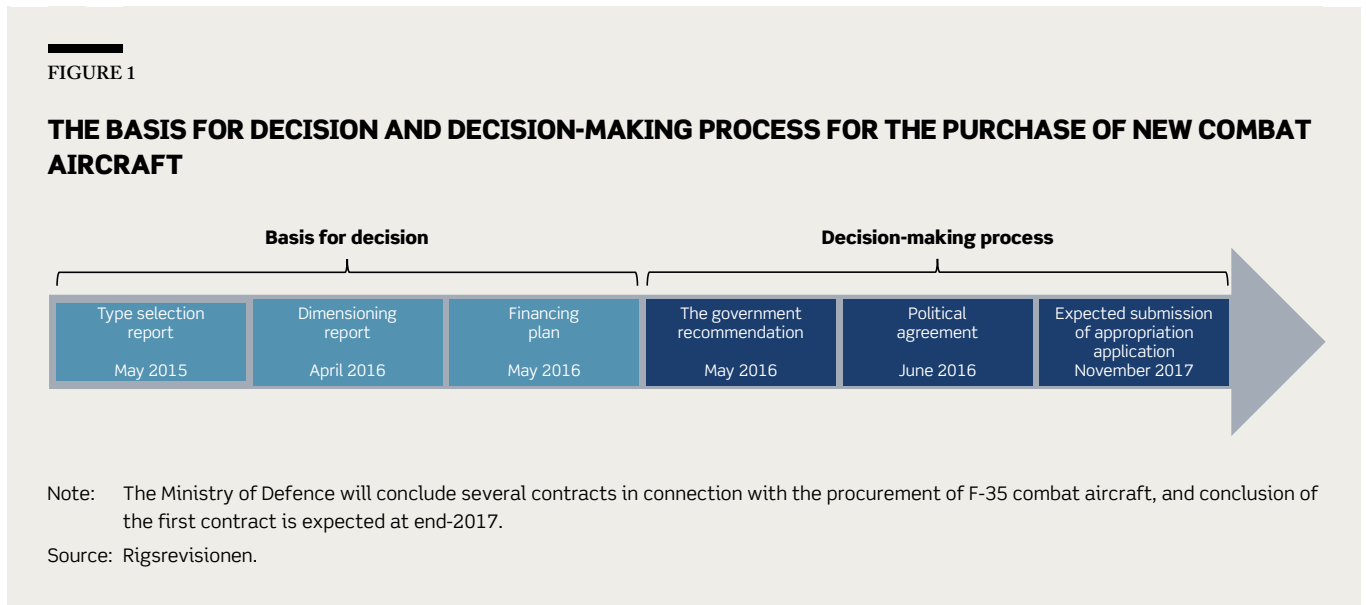


Figure 1 shows that the basis for a decision to purchase the combat aircraft consists of three elements: the report on the type selection of Denmark's future combat aircraft (the type selection report), the report from the Committee for the Dimensioning of New Combat Aircraft (the dimensioning report) and the financing plan. This basis for decision is the background for the government's recommendation to the parties to the agreement on the purchase of the combat aircraft that led to the political agreement. The political agreement will result in the preparation of a request to the Finance Committee of the Danish parliament, in which the Ministry of Defence seeks approval to procure and conclude contracts for the purchase of 27 F-35 combat aircraft.

12. The three parts of the basis for decision are described in the following:

*The type selection report* from May 2015 contains the results of the Ministry of Defence's evaluation of three combat aircraft candidates that were assessed and ranked according to four evaluation areas: strategic, military, financial and industrial aspects. The ministry's evaluation highlighted the F-35 combat aircraft as the best-ranking candidate in all four evaluation areas. The type selection report identified a need for 28 F-35 combat aircraft to perform the portfolio of tasks – six for instruction in the USA and 22 for task performance and training.

*The dimensioning report* is a supplement to the type selection report and contains an additional analysis of how many combat aircraft the Defence needs. The report concludes that the number of aircraft and pilots can be reduced and the portfolio of tasks still be performed. To this end, the Danish Defence must implement a series of optimisation measures as well as accept a number of assumptions and risks in addition to those already underlying the type selection report. The report showed that the number of F-35 combat aircraft required can thus be reduced from 28 to 27.

#### THE THREE COMBAT AIRCRAFT CANDIDATES

As well as the F-35 combat aircraft, the Eurofighter Typhoon and the F/A-18F Super Hornet were also selected as candidates for a new combat aircraft.

#### DIMENSIONING REPORT

The dimensioning report was prepared by a committee of participants from the Ministry of Defence, the Ministry of Finance, Defence Command Denmark and the Danish Defence Acquisition and Logistics Organisation.

According to the Defence Agreement 2013-2017, the Defence's purchase of combat aircraft must be financed within the defence budget. The Ministry of Defence has stated that, accordingly, the committee behind the dimensioning report has investigated all optimisation options for reducing the number of combat aircraft in the interest of the Defence's economy. The basis for decision shows there may be a risk that the 27 F-35 combat aircraft will be unable to perform the agreed tasks.

In the *financing plan*, the Ministry of Defence specifies the financing of the procurement and operational costs in the period 2018 to 2026, during which the combat aircraft are to be procured and phased-in. The bulk of the funding is to come from funding available in the Defence's acquisitions and logistics plan in the period 2018-2027. Additionally, the financing plan is based on the assumption that a number of efficiency measures in the Defence can free up funds.

#### *External quality assurance*

13. The type selection report and its underlying calculations, which are a central part of the basis for decision, have been subject to external quality assurance. The dimensioning report has not been subject to external quality assurance.

The external quality assurance served to assess whether the basis for decision provides a suitable basis for a political decision regarding type selection. Accordingly, the external quality assurance also put weight on the issue of equal treatment of the three combat aircraft candidates.

In the basis for decision, we have assessed only the information about the F-35 combat aircraft in relation to number and life-cycle costs. Hence, the purpose of our assessment of the basis for decision is different from the purpose of the external quality assurance.

#### **EXTERNAL QUALITY ASSURANCE**

The external quality assurance assessed the basis for decision according to five criteria: validity, completeness, consistency, relevance and presentation.

### **1.3. AUDIT CRITERIA, METHOD AND DELIMITATION**

#### **Audit criteria**

14. The purpose of the study is to assess whether the Ministry of Defence has provided an adequate basis for the decision to procure 27 F-35 combat aircraft.

In assessing whether the basis for the decision is adequate, we take the position that the calculation of the number of combat aircraft needed and the model for the analysis of life-cycle costs must be adequate. By this we mean that the calculations must be based on plausible assumptions and that the risks and uncertainty are adequately reflected.

By plausible assumptions, we mean assumptions underpinned by documentation showing that they can be expected to be realised with reasonable certainty. Examples of such documentation include data from past experience, information provided by the manufacturer (notably the RBI responses) or data from other authorities. By uncertainty we mean the possibility that an assumption cannot be realised to the extent expected.

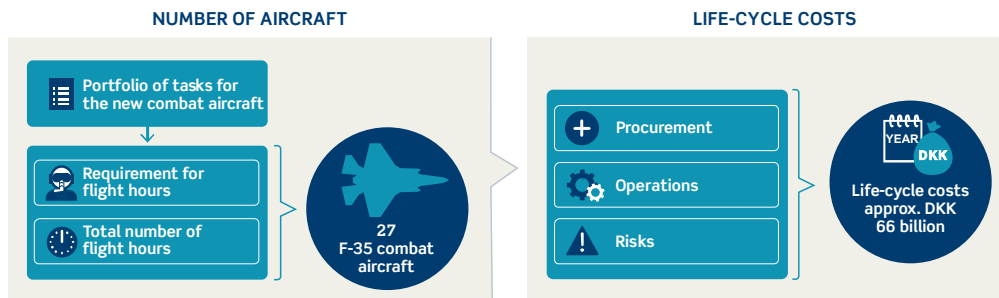
#### **RBI RESPONSES**

The manufacturer of the F-35 combat aircraft has provided binding information about the combat aircraft to the Ministry of Defence in the form of responses to the ministry's so-called Request for Binding Information (RBI).

15. Figure 2 shows how Rigsrevisionen has examined the calculation of the number of F-35 combat aircraft needed and how it affects life-cycle costs.

FIGURE 2

## INTERRELATION OF NUMBER OF F-35 COMBAT AIRCRAFT AND LIFE-CYCLE COSTS



Note: The figure reflects the focus of Rigsrevisionen's study. The basis for decision contains additional dimensioning factors that are not addressed in this study and therefore not included in the figure.

Source: Rigsrevisionen.

The left-hand side of Figure 2 shows how the calculation of the number of F-35 combat aircraft is based on the agreed tasks. The figure also shows that performing tasks requires a certain number of flight hours. This requirement must be met by the total number of flight hours, which for the F-35 determines the number of combat aircraft. The right-hand side of the figure shows how the 27 F-35 combat aircraft are the basis for calculating the costs related to procurement, operation and risks, which together make up the life-cycle costs.

16. In chapter 2, we examine the calculation of the number of combat aircraft required, and whether delivery of the agreed portfolio of tasks has been considered by the Ministry of Defence in its calculation of the requirement for combat aircraft. In this connection, we have examined whether the calculation assumptions concerning the required flight hours and the total number of flight hours are sufficiently evidenced, and whether the uncertainty related to the number of combat aircraft required is adequately reflected.

17. In chapter 3, we examine the model used for the analysis of life-cycle costs, which encompass costs related to procurement, operation and risk. We examine whether the Ministry of Defence has documented the assumptions for calculating life-cycle costs, and whether the procurement and operating risks are adequately reflected.

18. We have based this study's criteria on several factors that can be found in the earlier report from March 2009 regarding the basis for a possible acquisition of new combat aircraft. In that regard, Rigsrevisionen and the Public Accounts Committee identified a number of factors as significant for a basis for a decision to purchase new combat aircraft. In our opinion, several of these points are still relevant.

### Methodology

19. The study is based on the basis for a decision to purchase 27 F-35 combat aircraft, including the type selection report and the dimensioning report as well as underlying analyses. The financing plan is, however, not considered. In addition, the study is based on written material from the Ministry of Defence, including written accounts, presentations, memoranda and statements to the Finance Committee; material from the external quality assurance conducted; responses to the ministry's request for information from the manufacturer of F-35 combat aircraft; and other correspondence between the Ministry of Defence and the manufacturer.

The report has been prepared with a view to publication. In connection with the study, Rigsrevisionen has had access to classified and commercially confidential material that, for reasons of confidentiality, does not appear in the report. However, Rigsrevisionen assesses that the omitted information has had no bearing on the study's conclusions.

20. In connection with the procurement decision, the parties to the agreement have posed 103 questions to the Minister for Defence. In the study, we considered the responses to these questions as supplementing the analyses in the basis for decision.

21. We have held meetings with the Ministry of Defence where we, among other things, reviewed the ministry's calculation model. In the interests of financial materiality, we took a sample of a number of cost components totalling 60 per cent of the life-cycle costs, in order to examine the underlying assumptions and documentation of the cost items. However, we have not conducted a complete review of the selected cost components.

We have also held meetings with the US and Dutch supreme audit institutions (SAIs), respectively, to discuss the conclusions of their individual reports on the F-35 combat aircraft. We have further had a meeting with Hovedorganisationen af Officerer i Danmark, the trade union for Danish Defence officers, to discuss the proposed changes in pilots' working conditions. We have also received information regarding Norway's purchase of F-35 combat aircraft from the Norwegian SAI, which in that connection forwarded material to us from the Norwegian Ministry of Defence.

22. In the type selection report and dimensioning reports, the Ministry of Defence applies several identical assumptions to all three combat aircraft candidates. In our study, we assess the assumptions solely in relation to the calculation of the number and life-cycle costs of the F-35 combat aircraft.

23. The study's findings, sub-conclusions and main conclusion are based exclusively on analysis of the basis for decision, its underlying analyses and other relevant documentation from the period preceding the political agreement on the purchase of 27 F-35 combat aircraft. This notwithstanding, in chapter 1 we draw on more recent documentation that has emerged since the completion of the basis for decision, including information regarding other countries' procurement of F-35 combat aircraft. Chapters 2 and 3 contain comments based on more recent information that provide perspective. In some cases the Ministry of Defence's comments on the report refer to more recent information or they are substantiated by information that has become available after the basis for decision was completed.

24. In the study, we assess a basis for decision in which the purchase has not yet been effected. This means we are assessing the purchase at an early stage, for which reason certain conditions may already have changed with the appropriation application and contract conclusion.

25. The audit has been conducted in compliance with the standards for public-sector auditing; see Appendix 1.

### **Scope**

26. The study concerns the basis for a decision to procure 27 F-35 combat aircraft and the related life-cycle costs. The basis for decision was completed in 2016. We have only examined the elements of the basis for decision that relate to the number of F-35 combat aircraft and the financial issues. We have not directly addressed the parts concerning strategic, military or industrial issues. In the basis for decision, the socioeconomic consequences in the form of industrial cooperation are considered as being among the industrial issues, and are thus not comprised by this study. Accordingly, our study concerns one of the four evaluation areas contained in the basis for decision.

27. The study does not include an assessment of the JSF Program's progress in terms of the development of the F-35 combat aircraft as a whole. However, in the report, we occasionally refer to preliminary experience with the combat aircraft.

Nor have we assessed whether the number of employees in the Defence's logistics structure, including, for example, the number of mechanics, is sufficient to achieve the total number of flight hours and availability rate assumed.

Finally, the study does not include the actual financing of the combat aircraft procurement, nor does it address the financial flexibility of the Ministry of Defence budget, or whether the assumed efficiency measures can be implemented.

28. The methodology is described in Appendix 1, while Appendix 2 contains a glossary explaining certain words and concepts.

## 2. The Ministry of Defence's calculation of number of F-35 combat aircraft required

### SUB-CONCLUSION

#### REQUIREMENT FOR FLIGHT HOURS

The requirement for flight hours is the minimum number of flight hours that the Danish Defence requires to perform its portfolio of tasks.

#### WORKING CONDITIONS

The term working conditions includes the organisation of the pilots' work, working hours, pay and deployment conditions.

#### TOTAL NUMBER OF FLIGHT HOURS

The total number of flight hours is the number of hours that the Ministry of Defence has assessed that the 27 F-35 combat aircraft can fly in the course of 30 years.

Overall, the Ministry of Defence has based its estimate of the number of F-35 combat aircraft required on thorough analyses and calculations, but several key assumptions regarding the calculation of the requirement for flight hours and the total number of flight hours are associated with uncertainty. In Rigsrevisionen's opinion, the basis for decision should have highlighted these uncertainties, as these affect the ability of the 27 F-35 combat aircraft to perform all the required tasks.

To attain the fewest possible number of combat aircraft, the Ministry of Defence has, among other things, made assumptions regarding changes in pilots' working conditions that will help bring down the number of pilots. However, the basis for decision does not establish which of the proposed changes that can be implemented and how. Inability on the part of the Danish Defence to adequately realise the proposed changes in pilots' working conditions could indicate that the requirement for flight hours has been underestimated. Furthermore, the ministry has highlighted the risk that the number of pilots that routinely leave the Danish Defence might increase as a result of the changed working conditions, which might also indicate that the required number of flight hours has been underestimated.

In addition, the Ministry of Defence has not sufficiently evidenced the assumption concerning the 80 per cent synergy achievable between flight hours spent on international operations and training hours, as the assumption is based solely on a general presumption about the use of the new combat aircraft. The assumed synergy for a new combat aircraft is four times higher than what has been achieved with the F-16. The ministry has not assessed the uncertainty associated with the synergy assumption although the assumed synergy is of considerable importance for the calculation of the necessary flight hours and hence the number of combat aircraft needed.

The Ministry of Defence has calculated the total number of flight hours on the basis of plausible assumptions, but has not adequately reflected how uncertain the assumptions are. In light of the ministry's assumption of a higher average number of flight hours per combat aircraft per year, which is also high relative to, for instance, that of Norway and the Netherlands, it is particularly important to reflect the shortcomings of this assumption.

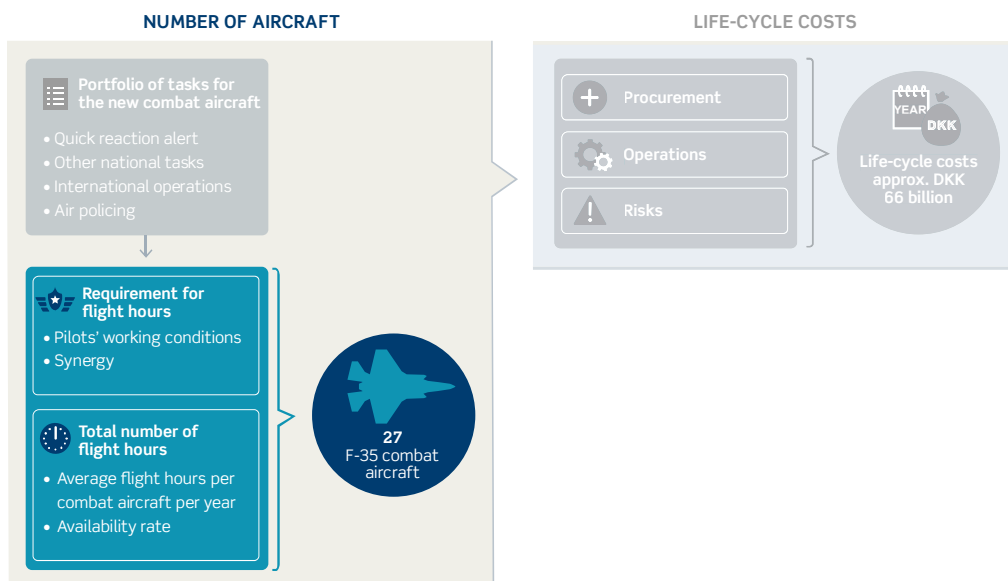
29. This chapter concerns the Ministry of Defence's calculation of the number of combat aircraft needed, including the assumptions and uncertainty related to the calculation.

The model used by the Ministry of Defence to calculate the number of F-35 combat aircraft is based on the agreed tasks and includes issues of material importance for the number of combat aircraft. The calculation model sets out more specific details concerning the tasks, for instance, deployment notice and frequency, average number of flight hours per flight relative to the individual tasks and number of flights per combat aircraft per 24 hours relative to the individual tasks.

30. Figure 3 shows the factors and interrelations used by the Defence in calculating the number of F-35 combat aircraft required.

FIGURE 3

### FACTORS AND INTERRELATIONS USED IN CALCULATING THE NUMBER OF F-35 COMBAT AIRCRAFT REQUIRED



Note: The figure reflects the focus of Rigsrevisionen's study. The basis for decision contains additional dimensioning factors and assumptions that are not addressed in this study and therefore not included in the figure.

Source: Rigsrevisionen.

As Figure 3 shows, the Ministry of Defence's calculation of the number of combat aircraft needed is based on the portfolio of tasks that the combat aircraft are to perform. Moreover, the calculation of the flying hour requirement includes assumptions about pilots' working conditions and the synergy between task performance and training. The figure also shows that the total number of flight hours is calculated based on factors such as average flight hours per combat aircraft per year, and that it is affected by the aircraft availability rate.



31. The Ministry of Defence's calculation of the number of F-35 combat aircraft needed is indicated in Box 4.

**BOX 4**

**CALCULATION OF THE NUMBER OF F-35 COMBAT AIRCRAFT NEEDED**

The Ministry of Defence has estimated the total requirement for flight hours over 30 years at 183,554 hours. The Defence's need for flight hours is highest in years with international operations. For example, the ministry has estimated that 7,791 hours will be required in 2027. The ministry has assumed that in years with international operations, each combat aircraft will be able to fly 290 hours on average. The ministry has used the following method to calculate the number of combat aircraft:

$$\text{Need for combat aircraft} = \frac{\text{Flying hours required in years with international operations}}{\text{Possible flying hours per combat aircraft per year}} = \frac{7,791}{290} = 27 \text{ combat aircraft}$$

Source: Rigsrevisionen on the basis of the Ministry of Defence's basis for decision.

## 2.1. REQUIREMENT FOR FLIGHT HOURS

32. We have examined whether the Ministry of Defence has based its calculation of the requirement for flight hours on plausible assumptions and whether the uncertainty is reflected.

33. In the basis for decision, the Ministry of Defence has calculated the necessary flight hours both in aggregate for the entire expected life span of the combat aircraft (30 years) and by year broken down by task performance, instruction and training. Table 1 shows the estimated number of flight hours required.

TABLE 1

### CALCULATION OF REQUIREMENT FOR FLIGHT HOURS IN THREE SELECTED YEARS AND OVER 30 YEARS

Tasks	Flight hours in years with international operations	Flight hours in year with air policing	Flight hours in years without international operations or air policing	Flight hours over 30 years (2020-2049)
Quick reaction alert	1,092	1,092	1,092	28,497
Other national tasks	500	500	500	11,544
International operations	4,992	0	0	39,936
Air policing	0	336	0	2,688
Instruction	1,207	1,229	1,229	36,077
Training	0	3,662	3,662	64,812
<b>Flight hours, total</b>	<b>7,791</b>	<b>6,819</b>	<b>6,483</b>	<b>183,554</b>

Note: The three years selected (2027, 2028 and 2029) are examples. There may be minor variations from year to year when the tasks are essentially the same.

Source: Rigsrevisionen on the basis of information from the Ministry of Defence.

As Table 1 shows, the number of flight hours required for the tasks to be performed by the combat aircraft, for instruction and for training varies over the years, with the highest requirement being in years with international operations.

34. The basis for decision shows that the annual requirement for flight hours is based on a number of factors, including various assumptions. For example, the number of flight hours in years with international operations is calculated on the basis of an assumption relating to pilots' working conditions and synergy. The assumption regarding pilots' working conditions has also had a bearing on the number of flight hours for pilot training and instruction in years with air policing and in years without air policing or international operations.

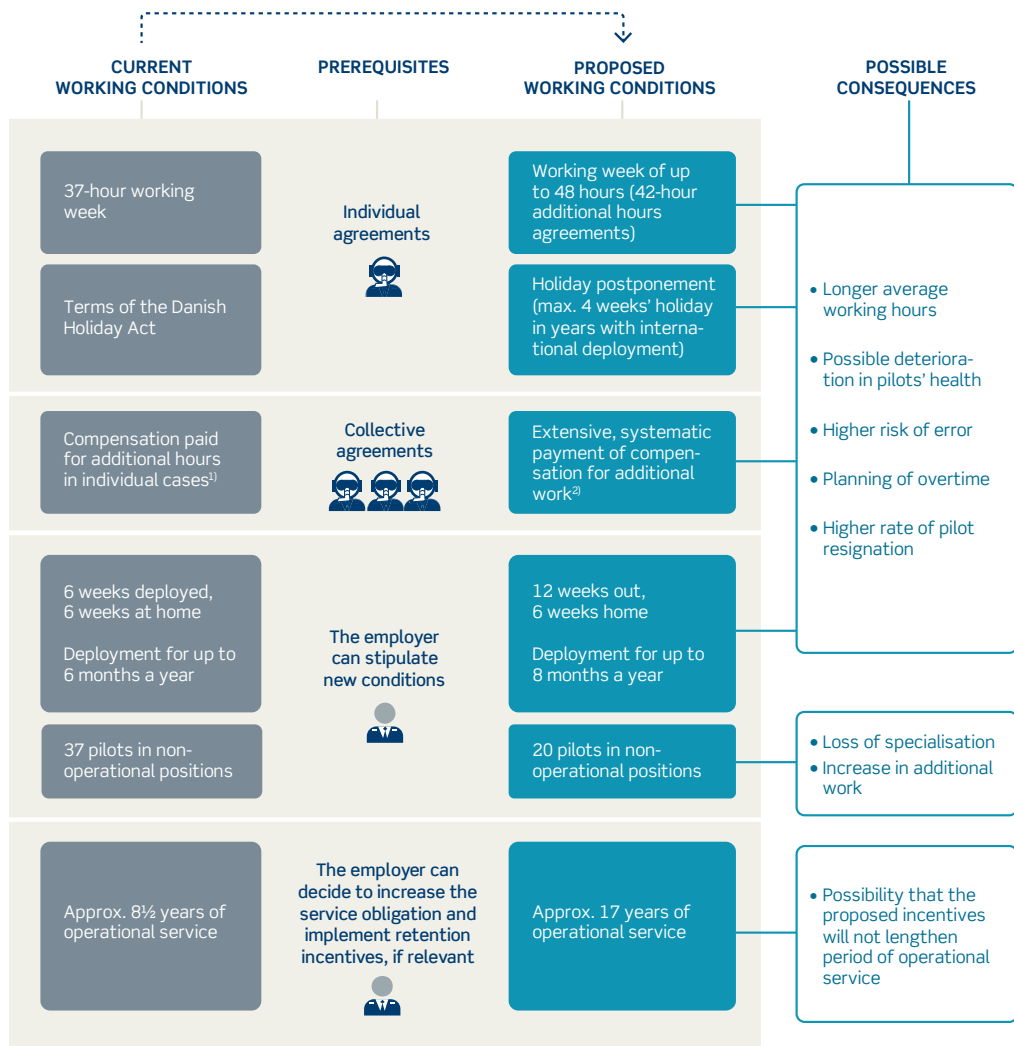
The following section reviews selected assumptions significant for the calculation of the required number of flight hours, and thus the number of aircraft needed. Rigsrevisionen assesses that greater uncertainty is associated with these assumptions than indicated in the basis for decision.

#### Pilots' working conditions

35. In the basis for decision the Ministry of Defence has presented a wide range of proposed initiatives for changing pilots' working conditions that can help reduce the need for pilots. These initiatives will reduce the required number of flight hours, as there will be fewer pilots needing instruction and training. Figure 4 illustrates the proposed changes and their possible consequences, along with the prerequisites that must be met before the Danish Defence can change the pilots' working conditions.

FIGURE 4

**THE MINISTRY OF DEFENCE'S PROPOSED CHANGES IN PILOTS' WORKING CONDITIONS, PREREQUISITES AND POSSIBLE CONSEQUENCES**



**ADDITIONAL HOURS AGREEMENT**

An additional hours agreement is an individual agreement between a pilot and the Ministry of Defence to increase the average weekly working hours from 37 to a maximum of 42. Pay, etc., will be increased proportionately. The pilots' collective agreement does not offer the possibility of additional hours agreements exceeding 42 hours.

**OPERATIONAL SERVICE**

Operational service denotes the total length of time that an employee is employed in a given operational position like, for instance, the time a pilot is employed in a position where flying combat aircraft is the primary task.

<sup>1)</sup> The possibility of compensation for additional hours worked depends on the individual pilot's employment status.

<sup>2)</sup> No agreement or rules exist that determine how many additional hours pilots may be eligible to receive payment for, but it may, in some cases, be contrary to the applicable agreement with Hovedorganisationen af Officerer i Danmark, the trade union for Danish Defence officers.

Source: Rigsrevisionen based on the basis for decision and information from the Ministry of Defence.

As Figure 4 shows, the proposed changes comprise initiatives concerning, for example, pilots' deployment period, which may increase from 6 to 12 weeks, and their weekly working hours, which may rise from a basic 37 hours to a maximum of 48 hours. The proposed changes also include an expectation that an increase in the length of the service obligation and new retention incentives might lead to a doubling of pilots' operational service from 8.5 years to approximately 17 years. According to the figure, examples of other possible consequences could be loss of specialisation, higher risk of error, deterioration in pilots' health, and higher resignation rates. The Ministry of Defence has stated that most of the proposed working condition changes will only apply during the performance of international operations every third year when it is operating at maximum capacity.

36. According to the basis for decision, it is uncertain whether the planned changes in pilots' working conditions can be implemented, and the assumption regarding fewer pilots will affect task performance, in general, because there will be fewer pilots to carry out the same tasks. Moreover, it is indicated that the initiatives will entail a risk that pilots will be unable to specialise to the same extent as before, and that a heavier workload will increase the risk of errors and greater deterioration in pilots' health.

Finally, it is stated that the proposed changes, among them longer working hours, may entail a higher rate of pilot resignation from the Danish Defence than expected.

37. The study shows that it has not yet been determined which of the proposed changes in pilots' working conditions that can be implemented and how: will it, for instance, be possible to conclude the necessary individual and collective agreements with the pilots, and will the retention incentives to increase the pilots' period of service have the desired effect. Furthermore, the basis for decision does not set out how the Ministry of Defence would combine the initiatives to obtain the necessary reduction in number of pilots and thus the expected reduction in flight hours needed.

Further, the study shows that the Ministry of Defence has highlighted uncertainties related to the proposed changes in pilots' working conditions and included some uncertainties in a risk assessment. The ministry's risk assessment is based on 28 F-35 combat aircraft. In connection with the reduction from 28 to 27 combat aircraft, the ministry proposed a number of significant changes in pilots' working conditions and highlighted a number of increased, new risks: a greater risk of more pilots resigning, a greater risk of deterioration in pilots' health, a lack of specialist expertise and the resulting impact on flight safety. The ministry has not updated the risk assessment with these new risks concerning pilots' working conditions.



*Pilot in F-35 combat aircraft.*

Photo: US Air Force Photo/Alamy Stock Photo

### **Synergy in conjunction with international operations**

38. According to the basis for decision that pilots' flight hours in conjunction with international operations can replace some of the hours pilots need to spend on training, because there is a synergy between the tasks performed and those in which training is required. An 80 per cent synergy is assumed for the new combat aircraft, which means that 80 per cent of the flight hours in years with international operations can replace training hours. As an example, 10 flight hours logged during international operations can also count as eight flight training hours. This reduces the expected number of required flight hours, as pilots' need for flight training hours is completely eliminated in years with international operations.

It is also indicated in the basis for decision that experience with F-16 combat aircraft shows a synergy of 12 to 22 per cent in connection with missions in Libya in 2011 and in Iraq in 2014 and 2015. In the basis for decision, the Ministry of Defence has not used these historical data as its basis on the grounds that the low synergy for F-16 combat aircraft is due to the aircraft's participation in simple types of mission. The ministry has stated that the 80 per cent synergy for F-35 combat aircraft is based on an assumption that the new aircraft are to be deployed in more comprehensive, complex types of mission. According to the ministry, flight hours in F-35 combat aircraft in connection with international operations can replace flight training hours to a greater extent than was the case with F-16 combat aircraft.

The Ministry of Defence has also stated that it has no further basis for determining or validating the degree of synergy, as there is uncertainty associated with the participation of Danish combat aircraft in international operations over the next 30 years. The degree of synergy achieved between international operations and training will be mission-specific, that is, the synergy effect will vary from mission to mission. Finally, the ministry has disclosed that if missions include only simple types of task, all else being equal, the synergy will be below the expected 80 per cent.

Finally, it is stated in the basis for decision that inability by the Danish Defence to achieve the assumed synergy of 80 per cent will have consequences for the performance of the agreed tasks and affect, for instance, which missions the Danish Defence can participate in during international operations, when and how often it can take part in missions, and the possibilities for maintaining deployment readiness. The Ministry of Defence has stated that lower synergy will probably mean that the Danish Defence will have to make up for a training lag before it can resume performance of all the agreed tasks.

39. The study shows that the Ministry of Defence has no experience or other data to support the 80 per cent synergy assumption, and that the figure primarily derives from the assumption about a change in the types of mission the combat aircraft are to carry out in future. The ministry has not reflected the uncertainty regarding synergy in the basis for decision, nor made allowance for the consequences of a possible failure to achieve the expected 80 per cent synergy, including a situation in which the Danish Defence primarily participates in simple mission types in future, as was the case with the F-16 combat aircraft. This could have a significant impact on the number of F-35 combat aircraft needed, since the ministry assumes that training, which makes up approximately half of the required number of flight hours, can be replaced by flight hours in connection with international operations. A fall in synergy would accordingly increase the need for training hours significantly.

The study also shows that Norway, for example, has not included synergy as an assumption in its calculation of number of F-35 combat aircraft required. The Norwegian Ministry of Defence has informed Rigsrevisionen that Norway has not used synergy as an assumption, because the degree of training achieved through international operations depends on the missions flown. The Danish Ministry of Defence has stated that it is not aware of other countries having included assumptions concerning synergy in their calculation of the need for combat aircraft either.

Further, the study shows that the synergy assumption has a significant impact on the required number of flight hours and thus the calculation of the number of combat aircraft needed. Accordingly, it is Rigsrevisionen's assessment that it is important to assess the uncertainty associated with the assumed synergy, as a failure to realise this assumption may have a bearing on whether the Danish Defence can perform the agreed tasks with 27 F-35 combat aircraft.

The Ministry of Defence has stated that the basis for decision elaborates on the matter of synergy. In this connection Rigsrevisionen observes that the synergy assumption is mentioned repeatedly in the basis for decision, but that the grounds for assuming a synergy of 80 per cent are based primarily on an assumption regarding a change in which types of mission the combat aircraft are to take part in, and that the associated uncertainty is not reflected. This uncertainty may have significant importance for whether the Danish Defence can carry out the agreed tasks with 27 F-35 combat aircraft.

## FINDINGS

The study shows that the assumptions regarding synergy and pilots' working conditions included in the Ministry of Defence's calculation of the required number of flight hours have not been sufficiently evidenced and that the uncertainty is not adequately reflected.

As regards pilots' working conditions, the extent to which the proposed changes can be realised has not yet been determined. Inability on the part of the Danish Defence to adequately achieve the proposed changes in pilots' working conditions could indicate that the requirement for flight hours has been underestimated. Furthermore, the Ministry of Defence highlighted the risk that the number of pilots that routinely leave the Danish Defence might increase as a result of the changed working conditions. A higher rate of pilot resignation will mean more new pilots will have to be trained, thus also increasing the requirement for flight hours.

As regards the synergy assumption, in the basis for decision the Ministry of Defence has based synergy on a general assumption about the use of new combat aircraft. The ministry has provided only very limited information about the basis for or uncertainty associated with the assumed synergy of 80 per cent. The synergy assumed for the F-35 combat aircraft is four times higher than that shown by experience with F-16 combat aircraft during two international operations in 2011 and in 2014 and 2015.

## 2.2. TOTAL NUMBER OF FLIGHT HOURS

40. We have examined whether the Ministry of Defence has based its calculation of the total number of flight hours for 27 F-35 aircraft on plausible assumptions and whether the uncertainty is reflected.

41. In the basis for decision, it is indicated that the calculation of the total number of flight hours is based on the average number of flight hours per combat aircraft per year and the assumed availability rate. Another assumption is that each F-35 combat aircraft can log 250 flight hours a year on average in years without international operations or air policing. Furthermore, the basis for decision states that the operational tempo during international operations can be increased to the same extent experienced with the Defence's F-16 combat aircraft. Against this background, the Ministry of Defence has estimated that the average number of flight hours per combat aircraft can be raised to 260 hours in years with air policing and to 290 hours in years with international operations. The estimated total number of flight hours is also based on the assumption that the combat air fleet can achieve an availability rate of 70 per cent.

### AVAILABILITY RATE

The term availability rate denotes the percentage of the total fleet ready at any given time to take part in the task performance and, in other words, is not undergoing maintenance or unavailable for other reasons.

42. The study shows that in years without international operations, the Danish Defence plans on an average of 250 flight hours per combat aircraft. By way of comparison, our study shows that the USA plans on an average of 250 hours and the Netherlands 210, while Norway plans on an average of 168 hours; see Box 5.

## BOX 5

**PLANNED AND ACHIEVED AVERAGE FLIGHT HOURS PER COMBAT AIRCRAFT AND AVAILABILITY RATE**

	<b>F-16 combat aircraft</b>		<b>F-35 combat aircraft</b>		
	<i>Danish Achieved</i>	<i>Danish Planned</i>	<i>US Planned</i>	<i>Dutch Planned</i>	<i>Norwegian Planned</i>
Availability rate	50%	70%	70%	-	-
Average flight hours per combat aircraft per year in years without international operations or air policing	165	250 <sup>1)</sup>	250	210	168

<sup>1)</sup> Average flight hours in years with international operations amount to 290 hours, while in years with air policing the figure is 260 hours and in years without international operations or air policing 250 hours.

Note: '-' indicates that we have no information on the subject.

Source: Rigsrevisionen on the basis of information from the Ministry of Defence (Danish figures), the Operational Test & Evaluation Office of the US Department of Defense and the Dutch and Norwegian SAIs.

According to the Operational Test & Evaluation Office of the US Department of Defense, the US Defense has not yet achieved the planned average number of flight hours per combat aircraft per year or the availability rate in the development of the combat aircraft. A report from the US Department of Defense shows that generally, achievement of the availability rate has developed positively, and that the highest availability rate achieved to date is 67%. However, the latest measurement showed an availability rate of 49%, but the Danish Ministry of Defence states that, according to its information, this was an isolated incident due to a fuel system fault that has been rectified. According to the ministry, at this stage of the aircraft's development, an availability rate of 67% is thus the most accurate indicator, and achieving a rate of 70% is realistic.

43. The Ministry of Defence has stated that it cannot comment on other countries' targets for flight hours nor use such targets to establish its own assumptions. The ministry's reasoning is that other countries have other experiences and plans, and that these may, for example, be determined by political requests for a certain number of combat aircraft, national education systems and pilots' working conditions, or a different portfolio of tasks. The ministry is, however, aware that during periods of international deployment, other countries' flight hours will also exceed 250 hours per combat aircraft per year.

In a different context in the basis for decision, the Ministry of Defence has calculated a reduction in the total number of flight hours. This calculation, based on 28 F-35 combat aircraft, shows that an annual reduction of 10% in flight hours will increase the need for F-35 combat aircraft from 28 to 32. The ministry's calculation thus shows that a reduction in the number of flight hours per combat aircraft per year may significantly affect the Defence's need for combat aircraft.



44. The study shows that the Ministry of Defence has not conducted an uncertainty assessment, as such, regarding the assumed average number of flight hours per combat aircraft per year, but has presumed that the levels are achievable. In connection with the preparation of the basis for decision, the manufacturer has stated that an average of 250 flight hours per combat aircraft per year is possible. It is Rigsrevisionen's opinion that the uncertainty associated with the average number of flight hours per combat aircraft per year should be reflected. Particularly, since this assumption is set high in years with international operations, and because the ministry's calculations in a different context have shown that a reduction in number of average flight hours per year may affect the Defence's need for combat aircraft significantly.

The study also shows that the Ministry of Defence has not reflected the uncertainty associated with the availability rate. It is Rigsrevisionen's opinion that several factors, such as logistics structure and the maintenance concept, have a bearing on the achievement of the target availability rate. The study further shows that great uncertainty is associated with the Danish Defence's ability to achieve a 70% availability rate with 27 combat aircraft, which is the same as the US Defense plans to achieve with a combat air fleet of over 2,000 aircraft. Particularly, when taking into consideration that unforeseen maintenance of individual Danish combat aircraft will have far greater consequences, among other things, in the form of greater fluctuations in availability rate. It is therefore important to reflect the uncertainty of the availability rate.

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## FINDINGS

The study shows that the calculation of total number of flight hours is based on plausible assumptions regarding average number of flight hours per combat aircraft per year and availability rate, but that the Ministry of Defence has not reflected the shortcomings of these assumptions. In the light of the ministry's assumption of a high average number of flight hours per combat aircraft per year, also compared with, for example, Norway and the Netherlands, it is particularly important to reflect these shortcomings.

# 3. The Ministry of Defence's analysis of life-cycle costs

## SUB-CONCLUSION

In the basis for decision the Ministry of Defence has calculated the life-cycle costs for 27 F-35 combat aircraft at approximately DKK 66 billion over 30 years. Rigsrevisionen assesses that the Ministry of Defence has essentially employed an adequate calculation model, but that the calculation does not cover the costs of mitigating noise nuisance, and that not all the risks associated with the life-cycle costs are adequately reflected.

The Ministry of Defence's calculation of infrastructure costs does not cover the mitigation of increased noise levels. The F-35 combat aircraft emits significantly more noise than the F-16, and its noise impact is expected to exceed permitted limit values.

The calculated costs of covering risks and fluctuations in the life-cycle costs do not reflect the risks associated with certain key assumptions, including synergy.

Furthermore, the risk costs calculation is based on the purchase of 28 F-35 combat aircraft. Hence, these costs do not reflect a number of new risks identified in connection with the decision to procure 27 F-35 combat aircraft.

Thus, the calculated risk costs are probably too low, and the life-cycle costs may be higher than projected in the basis for decision. The Ministry of Defence has stated that this will have no immediate bearing on life-cycle costs, but is expected to affect the Defence's ability to perform the agreed tasks.

45. This chapter deals with the Ministry of Defence's analysis of the life-cycle costs associated with purchasing 27 F-35 combat aircraft, including the expected costs of covering risks and fluctuations in life-cycle costs. The ministry has employed a calculation model based on the agreed tasks for new combat aircraft that covers factors with a significant bearing on life-cycle costs.

46. Figure 5 shows the Ministry of Defence's calculated life-cycle costs of purchasing 27 F-35 combat aircraft over 30 years.

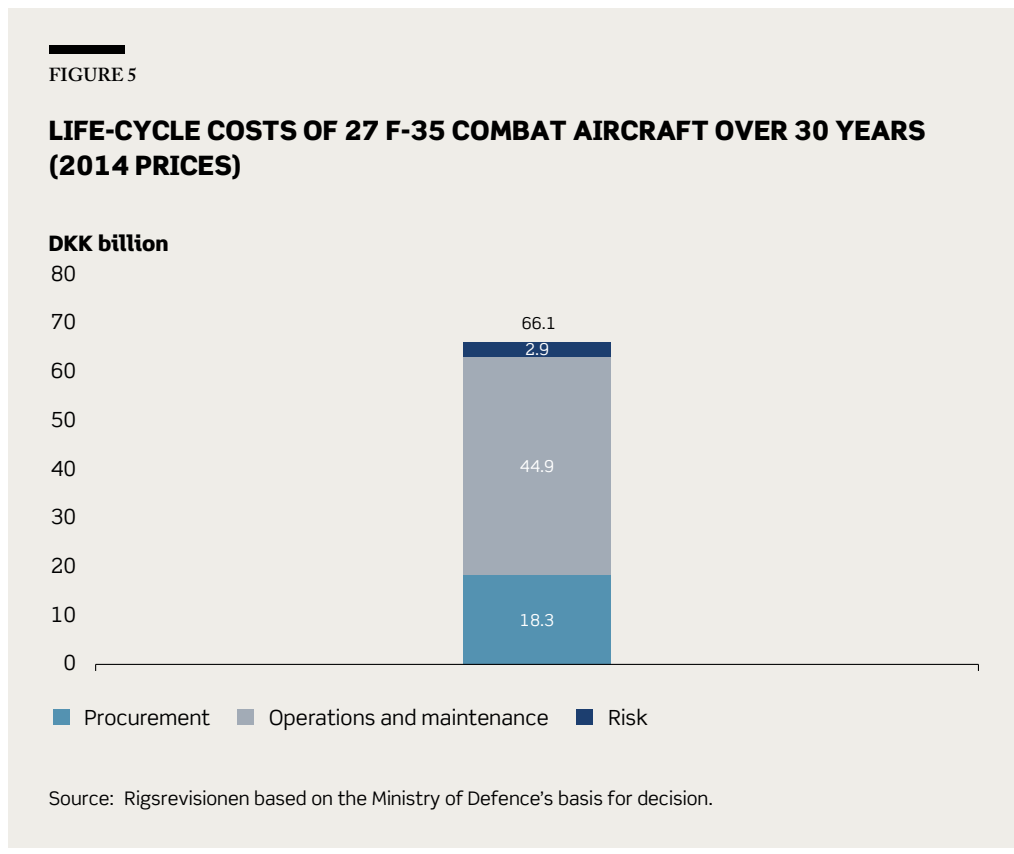


Figure 5 shows that the Ministry of Defence has calculated the total life-cycle costs of 27 F-35 combat aircraft at DKK 66.1 billion, an amount that comprises procurement costs of DKK 18.3 billion, operational costs of DKK 44.9 billion and risk costs of DKK 2.9 billion.

47. The Ministry of Defence has calculated the procurement and operational costs of 27 F-35 combat aircraft by using a model based on the agreed tasks and including factors known to have a significant impact on life-cycle costs.

48. The procurement costs cover the period up to 2026, when delivery of the last combat aircraft is expected, while the operational costs cover the full 30-year life span of the combat aircraft. The calculation model uses information provided by the manufacturer and Danish authorities (for example, the Ministry of Finance, the Danish Energy Agency and Danmarks Nationalbank (Denmark's central bank)) as well as the ministry's own data and analyses, primarily including experience data gained from the F-16 combat aircraft.

### 3.1. PROCUREMENT AND OPERATIONAL COSTS

49. We have examined whether the Ministry of Defence's assumptions for calculating the procurement and operational costs of 27 F-35 combat aircraft are documented in the basis for decision. The life-cycle costs can be divided into procurement and operational costs and risk costs.

The costs in the Ministry of Defence's calculation model are based on a series of recommendations that the ministry received in 2011 further to its earlier work of preparing a basis for a possible acquisition of new combat aircraft.

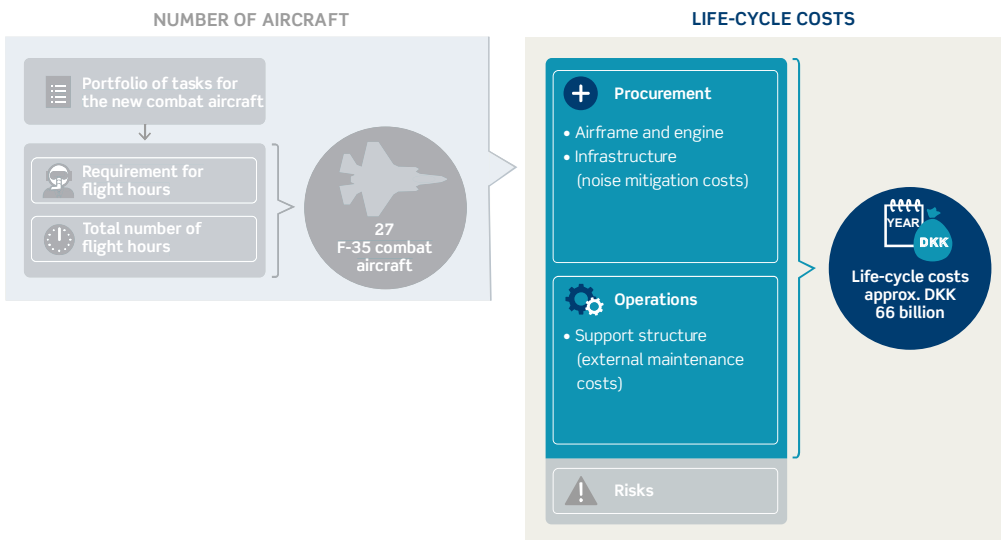
#### Procurement and operational cost components

50. We have reviewed a number of procurement and operational cost components: airframe and engine, spare parts (costs of participating in the global spares pool), infrastructure, operations, external maintenance, modifications and upgrades. These costs have been selected on the basis of their financial materiality and amount to approximately 60% of total life-cycle costs. We have traced the selected cost components back to the information that formed the basis for the calculation.

51. Figure 6 shows three of the selected procurement and operational cost components that we have examined in more detail.

FIGURE 6

#### SELECTED PROCUREMENT AND OPERATIONAL COST COMPONENTS



Note: The figure reflects the focus of Rigsrevisionen's study. The basis for decision contains additional cost items that are not addressed in this study and therefore not included in the figure.

Source: Rigsrevisionen.

Figure 6 shows that procurement comprises such cost components as airframe, engine and infrastructure, while operations includes cost components such as external maintenance.

Most of the data used to calculate the cost component comes from the manufacturer. The Ministry of Defence reviewed the manufacturer's data to ensure its applicability in a Danish context. In cases where it was not applicable, the ministry prepared its own analyses based on the manufacturer's data to obtain the most true cost picture. This information was then factored into the calculation model to enable the ministry to estimate the cost components. Box 6 shows an example of how airframe prices were calculated.

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**BOX 6****EXAMPLE OF CALCULATION OF AIRFRAME PRICES**

The Ministry of Defence asked the manufacturer to state the price of a certain number of airframes and received an answer. The manufacturer's stated prices were entered as a parameter in the calculation of the total airframe price. Other parameters such as payment plan and exchange rate were also factored into the calculation of airframe prices. On the basis of these parameters, the total procurement cost of the airframes was calculated and stated in the statement of costs. Airframe prices are included together with the other costs in the statement of total procurement costs.

Source: Rigsrevisionen on the basis of information from the Ministry of Defence.

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52. Our review shows that the Ministry of Defence can document the assumptions applied to the selected cost components. However, the costs of noise mitigation (included in infrastructure costs) do not cover the increased noise nuisance. Furthermore, the external maintenance costs (included in support structure costs) of F-35 combat aircraft depend, among other things, on a new maintenance concept and an IT system that is currently being developed. A review of these two assumptions follows below.

## Noise mitigation

53. In addition to the combat aircraft themselves, which are the primary cost, the procurement costs comprise infrastructure costs, including the conversion of Skrydstrup Airbase.



Skrydstrup Airbase from the air.

Photo: Royal Danish Air Force photo service, Defence Command Denmark

54. It is indicated in the basis for decision that the Ministry of Defence has carried out noise calculations, based on the Environmental Protection Agency's guidance, for the F-35 combat aircraft showing that noise levels will exceed the current noise limit values in certain areas. It is also indicated that the F-35 combat aircraft emits substantially more noise than the F-16 combat aircraft. This means that operating F-35 aircraft would subject the area surrounding the airbase to significantly more noise than the F-16s do. In the basis for decision, the ministry has calculated a number of optimisation measures to reduce the noise nuisance, but despite these measures the noise from the F-35 combat aircraft would still exceed the current noise limit values. The ministry has not made allowance for the cost of mitigating the increased noise nuisance in the basis for decision.

The Ministry of Defence refers to the fact that the level of the noise nuisance will only be known once the combat aircraft have been purchased and put into operation, and that the ministry will at that time take steps to reduce the noise nuisance. The ministry has stated that it also focuses on the noise impact of the F-35 combat aircraft in connection with the ministry's preparation of the appropriation application for the procurement of new combat aircraft. After completing the basis for decision, the ministry compiled an analysis regarding the conversion of Skrydstrup Airbase, which includes noise reduction measures; see Box 7.

## NOISE MEASUREMENTS

In connection with the type selection process, noise measurements were conducted for all three candidates on the basis of the RBI responses regarding the candidates' noise data. The aircraft noise measurements were conducted in accordance with the Danish Environmental Protection Agency's guidance on *Noise from aerodromes*. The results showed that all three candidates were noisier than the F-16 combat aircraft.

**TERMINAL NOISE**

Terminal noise consists of noise from the combat aircraft while at the airbase, but not noise produced when taking off, flying or landing.

**BOX 7****NOISE LEVELS PRODUCED BY F-35 COMBAT AIRCRAFT**

After completing the basis for decision, the Ministry of Defence conducted an analysis of the conversion of Skrydstrup Airbase and the expected related costs. The analysis shows that a noise barrier must be constructed to reduce the noise nuisance from the F-35 combat aircraft, which, according to the ministry's own calculations, emit significantly more noise than the F-16 combat aircraft and more than the permitted limit values. The planned noise barrier is expected to reduce terminal noise only, but not flight noise produced by the aircraft during take-off, flight or landing.

Source: Rigsrevisionen on the basis of information from the Ministry of Defence.

55. The Ministry of Defence has stated that funds have been allocated for noise mitigation measures after the basis for decision was completed. The ministry has also stated that it will conduct noise surveys for the purpose of obtaining a renewed environmental approval, and that the Danish Defence expects to be able to further reduce the noise of aircraft taking off and landing, among other things by changing the 24-hour distribution of flights, changing average flight length, further optimising flight paths and by a number of other noise-reduction measures, including conversion of the airbase.

56. The study shows that the costs of mitigating the increased noise nuisance are not included in the basis for decision, but that the Ministry of Defence has considered various noise mitigation issues since the basis for decision was completed.

The study further shows that in the ministry's subsequent analysis, it has estimated the costs of mitigating terminal noise, but not the increase in noise resulting from combat aircraft taking off, flying and landing.

Finally, the study shows that the Ministry of Defence has not accounted for any further costs of mitigating noise nuisance or for how the noise nuisance might impact on the use of the combat aircraft.

### External maintenance of the combat aircraft

57. According to the basis for decision, operational costs include the support system required to maintain the combat aircraft. It is also stated, in the basis for decision, that F-35 combat aircraft are primarily maintained through a global maintenance concept that differs from that for F-16 combat aircraft. The maintenance concept for F-35 combat aircraft is described in greater detail in Box 8.

#### BOX 8

### SUPPORT CONCEPT FOR THE F-35 COMBAT AIRCRAFT

The support concept for the F-35 combat aircraft functions on two levels, an operational level and a main maintenance, repair and overhaul (MRO) facility level. At the operational level – which, in the case of Denmark, is Skrydstrup Airbase – minor repairs, maintenance, component replacement, etc. are carried out. Major repairs are carried out at the main MRO facility level, and maintenance of the aircraft's individual components is carried out by external suppliers via the JSF Program's global maintenance concept.

The global support solution for F-35 combat aircraft is being developed by the JSF Program and is based on close collaboration between the countries that deploy the aircraft. This means that the Ministry of Defence owns the combat aircraft itself, while the JSF Program owns the components, spare parts and support equipment through a global spares pool. The aim is to minimise maintenance costs by having multiple users share a relatively small spares inventory and jointly procure spare parts. The maintenance concept for F-35 combat aircraft also includes using bonus-based agreements with external maintenance suppliers who are, for instance, rewarded for achieving low error rates and high availability rates. This approach is expected to lower overall maintenance costs.

The maintenance concept for F-35 combat aircraft means that the Defence in Denmark only needs to carry out less complex maintenance activities at the airbase, while external suppliers do major maintenance operations and repairs, eg, at MRO facilities in other countries that deploy F-35 combat aircraft.

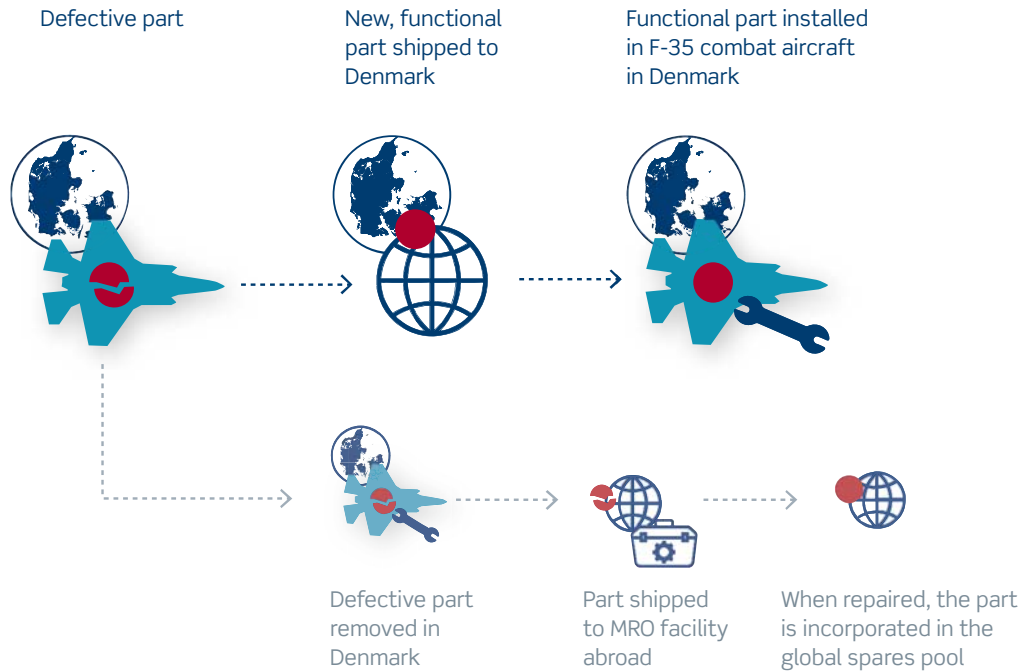
Source: Rigsrevisionen on the basis of information from the Ministry of Defence.



58. Figure 7 shows how the maintenance concept is expected to function when an F-35 combat aircraft needs repair, for instance, when a defective part needs replacement.

FIGURE 7

**THE EXTERNAL MAINTENANCE CONCEPT**



Note: The figure does not cover cases where the spare part is already available in Denmark, or in which a sub-supplier in Denmark can repair the part.

Source: Rigsrevisionen.

Figure 7 shows that when a defective part is to be replaced, the Danish Defence receives a new part from the global spares pool, which can be installed on the aircraft in Denmark. The defective part is removed in Denmark and sent for repair to an MRO facility abroad, after which it is incorporated in the global spares pool.

59. The Ministry of Defence's estimate of external maintenance costs has been calculated on the basis of information from the manufacturer and covers the costs of participating in the global maintenance concept. The global maintenance concept is still under development.



*F-35 combat aircraft is made ready for take-off.*

Photo: US Air Force Photo/Alamy Stock Photo

60. The basis for decision highlights the F-35's ability to self-diagnose faults and deficiencies that require maintenance and repair as an important aspect of the global maintenance concept. This information is also automatically transmitted to the suppliers via the Automatic Logistics Information System (ALIS). ALIS is described in brief in Box 9.

#### BOX 9

### **THE F-35 COMBAT AIRCRAFT'S IT SYSTEM, ALIS**

ALIS serves as the fundamental IT system of F-35 combat aircraft, supporting operations, mission planning, maintenance, etc. The system is structured according to functionality modules, and a maintenance module constantly monitors the aircraft and its component status. Whenever the maintenance module identifies faults, fatigue, etc, on the combat aircraft, the system orders the necessary components from the global maintenance concept's spares system, enabling them to be sent as swiftly as possible to the user for replacement.

Source: Rigsrevisionen on the basis of information from the Ministry of Defence.

61. In 2014, the GAO (Government Accountability Office of the US) published a report stating that ALIS was delayed by several years. The GAO concluded that this could have major ramifications for achieving the expected total number of flight hours. A summary of the GAO's most recent report regarding ALIS is set out in Box 10.

#### BOX 10

##### **DEVELOPMENT OF ALIS**

In April 2016 the GAO concluded that the system is still under development. The manufacturer continues to address problems with the system, and its development is delayed. The system was originally expected to be complete and ready for testing early in 2010, but this date has been pushed to end-2017.

Source: Rigsrevisionen on the basis of information from the GAO.

Rigsrevisionen notes that a failure of the maintenance concept and ALIS to function as expected may have an impact on the availability rate assumed for the F-35 combat aircraft. The Danish Defence's achievement of the availability rate assumed also depends on other factors, such as the planned number of employees in the Danish Defence's logistics structure, including mechanics.

## **FINDINGS**

The study shows that the Ministry of Defence has generally documented the assumptions underlying the calculation of the procurement and operational costs of 27 F-35 combat aircraft. However, the infrastructure costs are not fully reflected, which may mean they will be higher than estimated by the ministry in the basis for decision.

As regards infrastructure costs, the Ministry of Defence has not in the basis for decision examined possible initiatives for and costs of reducing the increased level of noise generated by F-35 combat aircraft, which is expected to exceed permitted limit values. Since the completion of the basis for decision, the ministry has considered various noise mitigation issues.

As regards the external maintenance of the F-35 combat aircraft, the Ministry of Defence's cost calculation depends, among other things, on an as-yet untested maintenance concept and the delayed ALIS IT system, still under development. There is a risk associated with the ongoing development of the external maintenance concept and the ALIS IT system, which may result in higher life-cycle costs or an inability to achieve the expected availability rate.

### 3.2. RISKS RELATED TO LIFE-CYCLE COSTS

62. We have examined whether the Ministry of Defence's model for calculating the costs of covering risks and fluctuations in life-cycle costs adequately reflects all the risks associated with life-cycle costs. In the report, the term risks denotes all elements of uncertainty of significance for life-cycle costs.

In the basis for decision, the Ministry of Defence has divided the procurement risks into risks and uncertainties. The basis for decision indicates that the ministry has estimated the cost of covering risks and that these risks are comprised by the life-cycle costs. The ministry has also estimated a potential fluctuation interval for the life-cycle costs based on a number of uncertainties.

63. Figure 8 shows an example of how procurement and operational risks affect life-cycle costs.

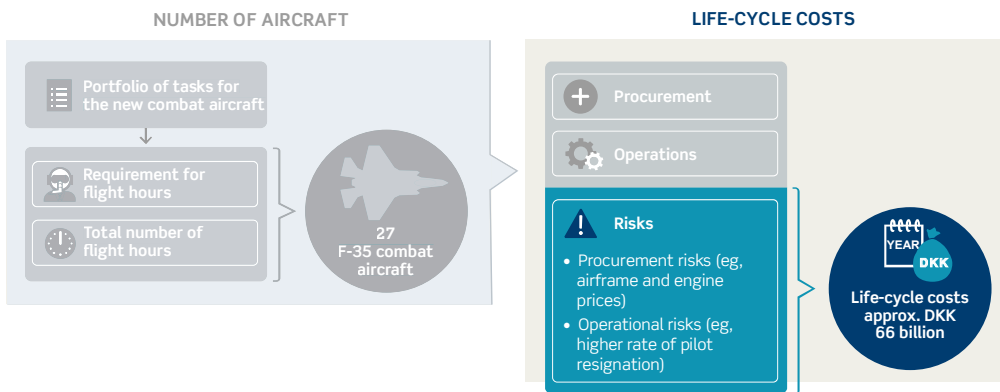
#### THE MINISTRY OF DEFENCE'S DEFINITION OF RISKS AND UNCERTAINTY

The Ministry of Defence defines risk costs as specific, but uncertain conditions that may occur, for which the ministry has assessed both the financial implications and the probability.

The Ministry of Defence defines uncertainty as an unquantifiable entity, typically because it depends on multiple parameters or incidents and because the financial implications of an uncertainty could potentially assume a continuum of values.

FIGURE 8

#### CORRELATION BETWEEN THE RISK COSTS INCLUDED IN THE MINISTRY OF DEFENCE'S ESTIMATE OF LIFE-CYCLE COSTS



Note: The figure reflects the focus of Rigsrevisionen's study.

Source: Rigsrevisionen.

64. The basis for decision shows that the Ministry of Defence has estimated the costs of covering risks at DKK 2.9 billion, 60% of which relate to procurement and 40% to operations. This estimate includes the cost of purchasing more combat aircraft, instructing and training more pilots, and higher payroll costs.

The risk cost calculation is based on an assessment of the financial implications and probability of each individual risk. The risk costs comprise only risks for which the Ministry of Defence has assessed that sufficient information was available to determine a financial implications and probability factor.

65. The study shows that risk costs have been estimated based on a risk analysis for 28 F-35 combat aircraft, and that the costs have not been updated in connection with the reduction of the number of F-35 combat aircraft to 27. The Ministry of Defence has thus not conducted an updated risk assessment for the purchase of 27 F-35 combat aircraft, despite a number of increased and new risks entailed by the reduction from 28 to 27 combat aircraft. For example, the basis for decision shows that the proposed changes in pilots' working conditions increase the risk of higher pilot resignation rates, loss of specialist expertise and resulting consequences for flight safety. The ministry has not updated the risk assessment with these new risks nor estimated their costs in the planned risk costs. Hence, the DKK 2.9 billion in risk costs does not reflect all the risks identified by the ministry in connection with the basis for decision.

#### BONUS-BASED AGREEMENTS

Bonus-based agreements are expected to be prepared through the JSF Program. The contracts are expected to reward external suppliers for low error rates and higher availability rate.

66. The basis for decision also shows that the Ministry of Defence has included a potential saving in risk costs, as it has factored in a gain of approximately DKK 800 million. This saving derives from bonus-based agreements with external maintenance suppliers. The potential savings have been included in the risk costs, which have thus been reduced to DKK 2.9 billion.

67. The basis for decision also indicates that the Ministry of Defence has estimated a fluctuation interval indicating that the life-cycle costs of 28 F-35 combat aircraft are highly likely to lie between DKK 60 billion and DKK 87 billion. To calculate this interval, the ministry has estimated the risk partly on information from the manufacturer and partly on macro-economic factors. The ministry has included risks for which it has assessed that a probable outcome space could be determined. For example, the ministry has assumed that the airframe and engine price used to estimate life-cycle costs may increase by 25% or fall by 10%.

The greatest risk factor is the exchange rate that affects the costs of both procuring and operating 27 F-35 combat aircraft. To illustrate the significance of the exchange rate, the Ministry of Defence made a calculation that isolated and excluded the exchange rate component. The calculation shows that when this risk is excluded, the fluctuation is smaller, between DKK 67 billion and DKK 74 billion. The ministry expects that the element of exchange rate risk associated with procuring the combat aircraft themselves can be managed through foreign currency hedging.

68. The study also shows that the risk associated with some key assumptions – including the synergy between international operations and training, average number of flight hours per combat aircraft per year and availability rate – is not reflected in, for instance, the risk costs. As our review in chapter 2 shows, the shortcomings of these assumptions are not reflected in connection with the calculation of number of combat aircraft either.

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## FINDINGS

The study shows that the Ministry of Defence has included relevant calculations of the risks associated with life-cycle costs in its basis for decision. However, in connection with the reduction of the number of F-35 combat aircraft to 27, the ministry did not update the calculation of risk costs or potential fluctuations in life-cycle costs, even though, during the reduction process, it identified a number of new risks of considerable potential significance for the life-cycle costs. Furthermore, the risk associated with some key assumptions, including the assumption of high synergy between international operations and training, is not reflected in the costs of covering risks, for instance.

Rigsrevisionen, 4 October 2017

Lone Strøm

/Mads Nyholm Jacobsen

## APPENDIX 1. METHODOLOGICAL APPROACH

### Description of the study

The purpose of the study was to assess whether the Ministry of Defence has provided an adequate basis for the decision to procure 27 F-35 combat aircraft. In this light we have examined the following:

- Has the Ministry of Defence carried out an adequate assessment of whether the procurement of 27 F-35 combat aircraft will meet the level of ambition set out for Danish combat aircraft?
- Has the Ministry of Defence applied an appropriate model for the analysis of the life-cycle costs of procuring 27 F-35 combat aircraft?

The study involves the Ministry of Defence, including the government department, and the Danish Defence Acquisition and Logistics Organisation.

The study focuses on the period 2013 to 2016, that is, from resumption of the type selection process until the period immediately following the decision by the Danish parliament on 9 June 2016 to procure 27 F-35 combat aircraft.

The study's findings, sub-conclusions and main conclusion are based exclusively on analysis of the basis for decision, its underlying analyses and other relevant documentation from the period preceding the political agreement on the purchase of 27 F-35 combat aircraft. This notwithstanding, in chapter 1 we draw on more recent documentation that has emerged since the completion of the basis for decision, including information regarding other countries' procurement of F-35 combat aircraft. Chapters 2 and 3 contain comments based on more recent information that provide perspective. In some cases the Ministry of Defence's comments on the report refer to more recent information or they are substantiated by information that has become available after the basis for decision was completed.

### Key documents

The study's findings are based on a review of analyses, memoranda and other documents from the Ministry of Defence prepared in connection with the basis for decision. The purpose of the document review is to answer the study questions and assess whether the Ministry of Defence has provided an adequate basis for a decision to procure 27 F-35 combat aircraft.

The material we have reviewed includes the following:

- the Ministry of Defence's type selection report and underlying sub-analyses, calculation models and memoranda
- the report from the committee for the dimensioning of new combat aircraft and underlying documents
- reports, presentations and material resulting from the external quality assurance
- information provided by the manufacturer of F-35 combat aircraft to the Ministry of Defence
- memoranda from the Ministry of Defence to the Defence Committee of the Danish parliament
- the internal guidelines of the Danish Defence Acquisition and Logistics Organisation
- material provided by the Ministry of Defence to the government's Finance Committee.

As well as documents from the Ministry of Defence, we have also reviewed material obtained from other sources, including supreme audit institutions of other countries (Norway, the Netherlands and the USA) that have purchased or use F-35 combat aircraft.

### Meetings

We have held meetings with the Ministry of Defence's government department and the Danish Defence Acquisition and Logistics Organisation (including the New Fighter Program). The chief aim of the meetings was to give Rigsrevisionen insight into the Ministry of Defence's work of developing the basis for calculating the number of new combat aircraft, including F-35 combat aircraft, and the related life-cycle costs. Furthermore, the meetings have served to conduct a control of a number of selected cost items in the Ministry of Defence's calculation of number of combat aircraft and total life-cycle costs; see below. Finally, we have held meetings with the Ministry of Defence in connection with consultations regarding audit memoranda and the draft report.

We have held meetings with the US and Dutch supreme audit institutions, respectively, to discuss the conclusions of their individual reports on F-35 combat aircraft. In connection with the study, we have had discussions with the Norwegian SAI regarding Norwegian issues related to F-35 combat aircraft. In this context, the Norwegian SAI forwarded material from the Norwegian Ministry of Defence.

Finally, we have had a meeting with Hovedorganisationen af Officerer i Danmark, the trade union for Danish Defence officers, to discuss the proposed changes in pilots' working conditions.

### Selection and control of cost items

Taking the basis for decision as our starting point, we selected a number of cost items for control. The selection was based on an assessment of their financial materiality and uncertainty. In selecting the items, we put weight on the following:

- how large a percentage of total costs the individual item represents
- whether the cost appears robust and well-documented
- whether risks and/or uncertainties are associated with the cost.



We have conducted a more detailed control of the selected cost items in the Ministry of Defence's analysis of the life-cycle costs of 27 F-35 combat aircraft.

The purpose of the control was to obtain assurance that the Ministry of Defence's calculation model correlated with data provided by the manufacturer and experience data for F-16 combat aircraft, including the use of this data.

Among other things, the control process entailed meetings with the Ministry of Defence, where we were shown the manufacturer's information and the calculations incorporated in the basis for decision. The control process consisted of a review of the analysis of the selected cost items, in which we followed the calculation of the cost item from the manufacturer's information and the Ministry of Defence's data processing to the final calculations in the financial calculation model. We have subsequently received data processing extracts. We have not received the material nor had an opportunity to independently review the material contained in the financial calculation model or the manufacturer's information. We consider our access to the selected data material as adequate.

#### **Standards for public-sector auditing**

The audit has been conducted in compliance with the Danish standards for public-sector auditing. The standards set out what users and the public can expect from a highly professional audit product. The standards are consistent with the Fundamental Auditing Principles of the International Standards of Supreme Audit Institutions (ISSAI 100-999).

## APPENDIX 2. GLOSSARY

<b>Quick reaction alert capability</b>	Two combat aircraft + standby aircraft ready to take-off at extremely short notice to intercept unidentified or undesired aircraft in Danish air space.
<b>Air policing</b>	Danish maintenance of a quick reaction alert capability for a limited period for a NATO country that does not have its own combat aircraft capability, eg, Iceland and the Baltic countries.
<b>ALIS</b>	The IT system installed in the F-35 combat aircraft that monitors the aircraft's systems and forwards information about any faults and deficiencies identified for maintenance purposes.
<b>Requirement for flight hours</b>	The total number of flight hours required by the Danish Defence for task performance, instruction and training.
<b>Total number of flight hours</b>	The number of flight hours that the support structure can produce for the given combat aircraft.
<b>The JSF Program</b>	An international program organisation comprising the USA and eight partner countries, including Denmark, responsible for the development of the F-35 combat aircraft together with the manufacturer, Lockheed Martin.
<b>Life-cycle costs</b>	The total costs of procuring and operating, eg, combat aircraft, throughout their expected life span.
<b>Period of operational service</b>	The total length of time that an employee is employed in a given operational position, eg, the time a pilot is employed in a position where flying combat aircraft is the primary task
<b>Standby aircraft</b>	Aircraft available for a given task to ensure that the required number of aircraft can be used at any time for a given task and thus compensate for the potential unavailability of some combat aircraft.
<b>Availability rate</b>	The percentage of a total fleet ready to take part in the task performance at any given time and which is thus not undergoing maintenance or otherwise unavailable.
<b>Smart Defence</b>	General term for multinational solutions that generate more capability at the same cost or the same capability at less cost, achieved eg, by NATO countries prioritising and specialising in capabilities that NATO lacks, or by building capabilities in partnership with other countries.
<b>Terminal noise</b>	Noise from combat aircraft while operating at the airbase, but not noise produced during take-off, flight or landing.
<b>Service obligation</b>	Indicates the length of time for which an employee is contractually bound to the job. If the employee hands in notice or is in breach of contract for no valid reason before the contract expires, the employee may be found liable to pay damages.