Developing a C4I Architecture for the Netherlands Armed Forces

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Abstract - **The purpose of this paper is to present the first results obtained in the development of a service-oriented C4I architecture for the Netherlands Armed Forces. New developments in military operations, such as NEC and EBO, call for higher levels of interoperability, both within the Netherlands Armed Forces and with its partners. Present-day missions of Dutch forces in Iraq and Afghanistan involve a wide range of coalition partners and other parties, with a wide range of *modi operandi* and levels of technical sophistication. This provides a challenge for the design of the Armed Forces' C4I architecture. Agility becomes an indispensable property. A C4I architecture is urgently required to translate policy into requirements and to provide cohesion and priorities between C4I requirements. In 2008 the Netherlands Defence Academy, together with TNO, started the development of the C4I architecture by identifying and interviewing its primary stakeholders, thus ensuring that the product would serve the intended purpose of its future users. Purpose and scope of the C4I architecture were defined. Development of the operational process model and information services model has been started. The paper provides an overview of the theoretical context, the chosen approach and initial results. Finally, some lessons learned are identified.**

I. Introduction

Motivation

In 2008 the Netherlands Defence Academy (NLDA) embarked on an effort to develop a C4I architecture for the Netherlands Armed Forces, as requested by the Netherlands Defence Staff. The NLDA cooperated in this effort with the Netherlands Organisation for Applied Scientific Research (TNO). The development of a Netherlands C4I architecture was already due for some years, so one might wonder: why this sudden urgency? Of course, the C4I architecture would provide more cohesion in the development of C4I requirements. And the requirement for more cohesion was certainly felt in the new Defence Staff, which was created in 2005 by amalgamating the former Navy, Army and Air Force Staffs. Up till that time, these staffs were used to develop their C4I facilities almost in splendid isolation from each other, without a common architecture.

But there were other, more compelling reasons. New developments in military operations, as identified in the Netherlands Defence Doctrine (NDD) [1] called for higher levels of interoperability, both within the Netherlands Armed Forces and with its partners. The NDD recognizes three new developments: military operations are increasingly joint (involving coordinated action by two or more services), combined (coordinated multi-national action), and integrated. Since each service may well have its own C2 system, joint and/or combined operations require the respective C2 systems to be capable of exchanging information, i.e. they must be interoperable. In other words, although the trends towards joint and combined operations are operational in nature, they have technological impacts. By contrast, integrated operation refers to technological developments that have an operational impact. The NDD identifies three such technological developments: the increasing importance of information operations, the introduction of Effects-Based Operations (EBO), and the transition to Network-Enabled Capabilities (NEC). Reference [2] specifies how and when the Netherlands Armed Forces should implement NEC, by stating the ambitions in terms of NEC maturity levels to be attained in specified timeframes.

These new developments on military operations were not only recognized in the Defence Staff. They were experienced on the ground, by Dutch forces engaged in military operations in Iraq and Afghanistan.

Recent Operational Experience

Deployed and mobile operational staffs and units of the Netherlands Armed Forces assigned to a mission will in principle always be operating as building blocks within an international force. This implies that their C4I facilities should also take the form of building blocks within an international C4I structure, consisting of national contributions from the participating nations. This international C4I environment points at the necessary international dimension of the C4I architecture. Indeed, the international environment defines to a large degree what the national C4I architecture should look like.

Present-day missions, such as the current deployment of Dutch forces in Afghanistan, involve a wide range of coalition partners and other parties, including non-NATO forces, local authorities and non-governmental organisations. Dutch forces must cooperate and exchange differing information with each of these partners. This wide range of partners and other parties shows a correspondingly wide range of *modi operandi* and levels of technical sophistication. This scenario is further complicated by its evolving nature. Partners and other parties involved in a mission change over time, and can be completely different in the next mission.

From a doctrinal perspective, this new operational reality is a example of the EBO theory put into practice. EBO recognise that the desired outcome can often be best reached by employing a mixture of military and non-military means, e.g. defence, diplomacy, and civil development (the "3 Ds"). This implies that military C2 systems must support an operational process that incorporates both military and non-military information and actions. Moreover, military C2 systems must be interoperable with their civilian equivalents, i.e. information systems in other Ministries (e.g. Justice, Internal Affairs, External Affairs, and Overseas Development), in the emergency services (e.g. police, fire, ambulance, and rescue services), in international organisations (e.g. the EU and the UN), in non-governmental organisations (NGOs), in suppliers, and even in the media.

To say that this provides a challenge for the design of the Armed Forces' C4I architecture would be an understatement. However, one thing is clear. To cope with this continuously changing environment, agility becomes an indispensable property, and the C4I architecture should be designed to support this.

Evolving Architecture Research Efforts

The involvement of the Netherlands Defence Academy (NLDA) is a follow-on of architecture research by the Netherlands Organisation for Applied Scientific Research (*Organisatie voor Technisch Natuurkundig Onderzoek*, TNO) in 2007. For the research effort required to develop a C4I architecture, NLDA teamed up with TNO. In coordination with the Defence Staff, NLDA and TNO developed a Programme of Work (PoW) for 2009. We used *inter alia* the US Department of Defense Architecture Framework (DoDAF) [3] for the development of the PoW.

DoDAF mandates that as a first step in the development of the architecture, its intended use should be defined. To this end, the primary stakeholders of the C4I architecture were identified, and structured stakeholder interviews were conducted. The outcome of these interviews was taken into account in the development of the Programme of Work. It was agreed that the stakeholders would be kept closely involved in the architecture development. This should ensure that the C4I architecture serves the intended purpose of its future users. Above all, it must not become a purpose in itself, a common pitfall in architecture development [4]. Another activity in this initial stage, important to create focus, was the definition of the purpose and scope of the C4I architecture to be developed.

Purpose and Scope of Paper

The purpose of this paper is to present the first results obtained in the development of a service-oriented C4I architecture for the Netherlands Armed Forces. We consider it important to test our findings with our strategic partners, because of the Netherlands ambition to reach NEC maturity level 3 with its strategic partners in 2010. For this reason we would welcome any comments at this stage.

Of the various C4I architecture products to be developed, only the products to be developed by NLDA and TNO will be discussed, i.e. the operational process model and the operational information services model.

Paper Structure

Following this introduction, in the next chapter the theoretical context of the C4I architecture will be described, being the Netherlands Defence Information Architecture, and its relations with other architecture frameworks. This will be followed by a description of the approach taken, as laid down in the Programme of Work. The next two chapters provide some initial results: the conduct and outcome of stakeholder interviews, and initial steps in the development of process and services models. Finally, some initial lessons learned are provided, together with an overview of (possible) follow-on research.

II. Theoretical Context

Architecture Definitions

Reference [5] defines a systems architecture as:

"the fundamental organisation of a (software-intensive) system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution".

The intended purpose of developing a C4I architecture is essentially captured by [6]:

"an architecture description is a formal description of a system, organized in a way that supports reasoning about the structural properties of the system. It defines the (system) components or building blocks … and provides a plan from which products can be procured, and systems developed, that will work together to implement the overall

system. It thus enables you to manage … investment in a way that meets (business) needs …"

This implies that for this research, the C4I facilities of the Netherlands Armed Forces are collectively approached as one comprehensive system. This is a valid approach, since they collectively show the characteristics of a system as described in [7]:

- *they have a structure that is defined by its parts and processes;*
- *the Netherlands C4I system is a generalisation of reality;*
- *the system parts have functional as well as structural relationships.*

This system-characteristic should not detract us from another important aspect. As mentioned before, to support nowadays operational missions, national C4I facilities should take the form of building blocks within an international C4I structure, consisting of national contributions from the participating nations.

Architecture Frameworks

There is a great variety of architectural styles in the scientific literature, such as client-server architectures, component-based architectures, blackboard systems, model-view-controller, modular plug-in architectures, layered architectures, and peer-to-peer architectures. In selecting an architecture style and framework, the aforementioned international dimension of the C4I architecture should be taken into account. The C4I architecture will comply with the principles of third-generation C2/C4I system architectures, as implemented in the NATO Architecture Framework (NAF) [8], the US DoD Architecture Framework (DoDAF) [3], and especially the Netherlands Defence Information Architecture (*Defensie Informatie Voorzienings Architectuur*, DIVA) [9].

DIVA is not an architecture framework, but a corporate information architecture for the Netherlands Defence. In 2007 TNO has performed a comparative study of DIVA, DoDAF, NAF and other architectures [10], the findings of which will be used in the development of the C4I architecture. Specific tools, model views, and methods developed for these architectures could be applied for the Netherlands C4I architecture. They could also be proposed as additions to DIVA.

The DIVA Model

DIVA is a 3-level architecture (see fig. 1), like NAF and DoDAF. The upper layer contains the business processes, the middle layer the information services which support the upper layer, and the bottom layer contains the technology (i.e. ICT infrastructure) required for the middle layer. Across these 3 layers, DIVA is composed of three columns, from left to right: direction, composition and implementation (see fig. 1).

The Netherlands Chief Information Officer[1] (*Hoofddirecteur Informatie en Organisatie,* HDIO) is responsible for the development and maintenance of DIVA.

DIVA Supporting Architectures

DIVA is to be underpinned by a series of supporting architectures covering various architecture aspects and defence policy areas. Each supporting architecture should have the same DIVA structure. There are two types of supporting architectures: aspect-architectures and sub-architectures.

DIVA aspect-architectures cover aspects which are defence-wide and include information security and the ICT infrastructure (networks and communications). HDIO is responsible for the networks and communications aspect-architecture.

DIVA sub-architectures cover policy areas such as operations (C4I), personnel, materiel, finance etc. The Chief of Defence Staff[2] (*Commandant Der Strijdkrachten,* CDS) is responsible for operational policy and requirements, and for this reason also responsible for the development of the C4I architecture. This is the formal reason why a C4I architecture is needed: it is one of the supporting architectures of DIVA. The business process it supports is the operational process. The C4I architecture defines the information flow required to support the operational process, information services that should be in place, and operational information systems which provide such services.

DIVA and most of its supporting architectures have a business-like approach and have already been used and tested for the implementation of Enterprise Resource Programs (ERP). Some argue that, for that reason, its methods and tools are less appropriate for an operational process. This remains to be tested. For the development of the C4I architecture, DIVA methods and tools will initially be used. If limitations or shortfalls are encountered, alternative tools and methods, e.g. from NAF or DoDAF, could be proposed.

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[1] The translation of his Netherlands title is: Chief Director for Defence Information and Organisation.

[2] The translation of his Netherlands title is: Commander-in-Chief of the Netherlands Armed Forces

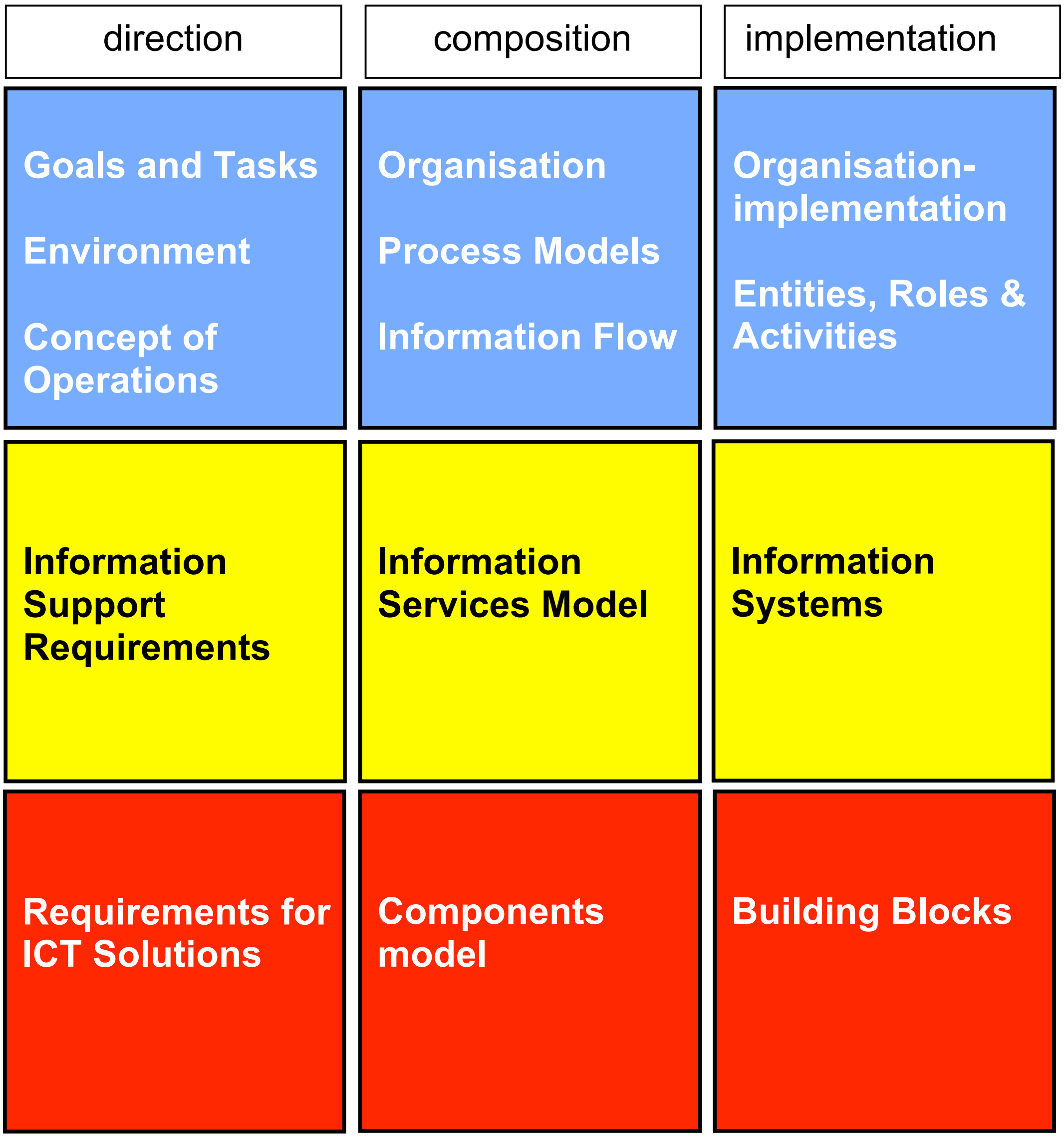

Fig. 1. The DIVA model

DIVA and Services

DIVA has mandated the Service-Oriented Architecture (SOA), in which software systems are built from software services. Services are relatively large units of functionality that are not *a-priori* associated with one another, i.e., they have no calls to one another embedded in them. Examples of services in a military context could be: geographical and oceanographical data support, prediction of acoustic propagation, advice on Rules of Engagements in force and related legal implications; computation of fire control solutions; analysis of large amounts of sensor data (e.g., pattern recognition); analysis of electromagnetic intercepts; advice on weapon and target selection; etc.

Instead of embedding calls to one another in their source code, services define protocols that describe how the services talk to one another. Based on these protocols, services can be linked and sequenced automatically in a process known as “service composition”. Research issues in SOA include protocol standards and service composition methods. Additional research issues specific to C4I include how to adapt services and SOAs to real-time requirements; bandwidth limitations; joint, combined and civil-military interoperability; agility and reconfiguration on-the-fly; and international regulatory constraints.

III. C4I Architecture Development Approach

C4I Architecture Products

As mentioned before, as a first step a Programme of Work (PoW) has been developed, in coordination with Defence Staff and the primary stakeholders. As part of this process, a number of architecture products were identified in the PoW to be developed initially. Table 1 lists the architecture products along with the intended content and purpose.

These architecture products should be developed iteratively, with each iteration in three steps:

a - collect information; b - develop first draft; c - review by stakeholders.

Some interdependencies exist between the various architecture products. Their development runs in parallel. Once a first draft has been developed, it will serve as input for other products. The development process as envisioned is depicted in fig. 2 below.

TABLE 1
C4I ARCHITECTURE PRODUCTS, CONTENT & PURPOSE

Architecture product	Content & purpose
C4I basic considerations & principles	Practical translation of various C4I policy documents, to provide guidance for architecture development
C4I standards and technologies	Definition of standards & technologies to be used for the development of C4I facilities and to improve interoperability
Checklist C4I requirement process	An easy to use tool, derived from existing policy and guidelines, to be used in the C4I requirements development process
Technical requirements and guidelines	A tool for Defence Staff to be used to formulate guidelines for C4I project realisation and C4I system management
Operational process model	A description of operational processes, providing information on required functionality, capacity and interoperability, to be used to develop a generic operational process model and to define operational information services
Operational information services model	A common reference for C4I requirements staff, developers and users to describe functionalities, which should promote reuse of services / system components and the definition of functional, rather than technical requirements

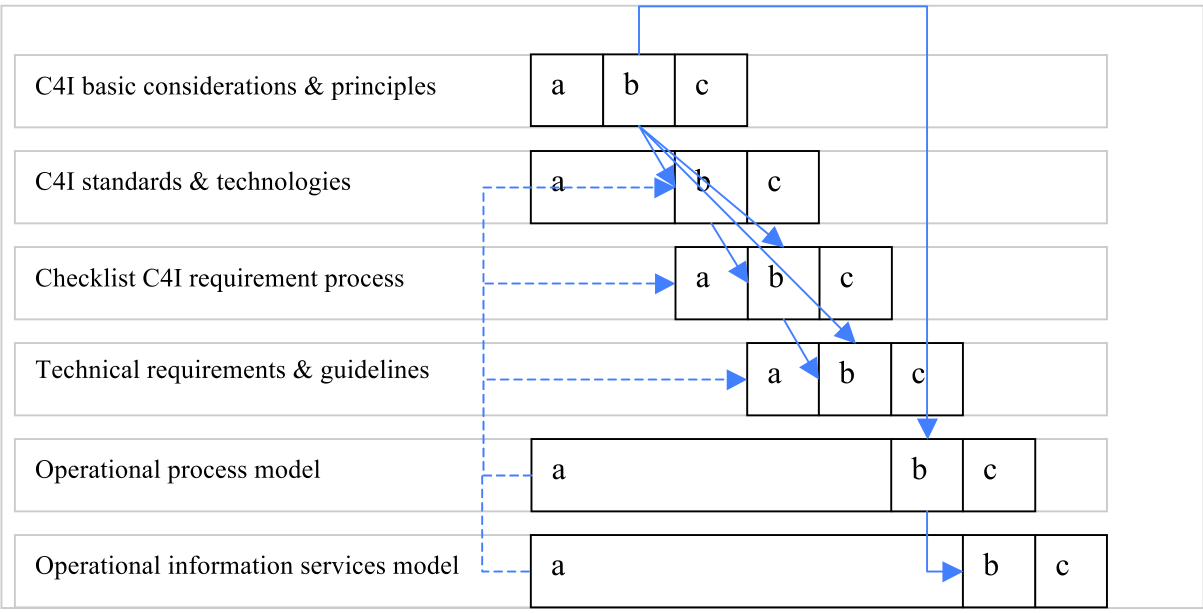

Fig. 2. C4I architecture products: interdependencies & parallel development.

C4I Architecture Development: Iterative and Evolutional

The Defence Staff advocates a pragmatic approach, resulting in early results which can be used and tested in practice by the stakeholders. With C4I architecture development starting early 2009, the first architecture products should be ready for use and tests as early as in the second quarter of 2009. This acceleration should be made possible by the active involvement of various stakeholders.

They agreed to take the responsibility for the development of various architecture products and to provide the personnel resources required.

It was agreed that TNO and NLDA will provide coordination support, and will develop the core of the C4I architecture: the operational process model and the operational information services model. Development of these models will take longer than the others. Development of all architecture products should be iterative and evolutional, as depicted in fig. 3. Iterations will initially consist of interim reviews by stakeholders, followed by the using and testing of initial versions of architecture products. Evolutions consist of additional architecture products to be developed after phase 1.

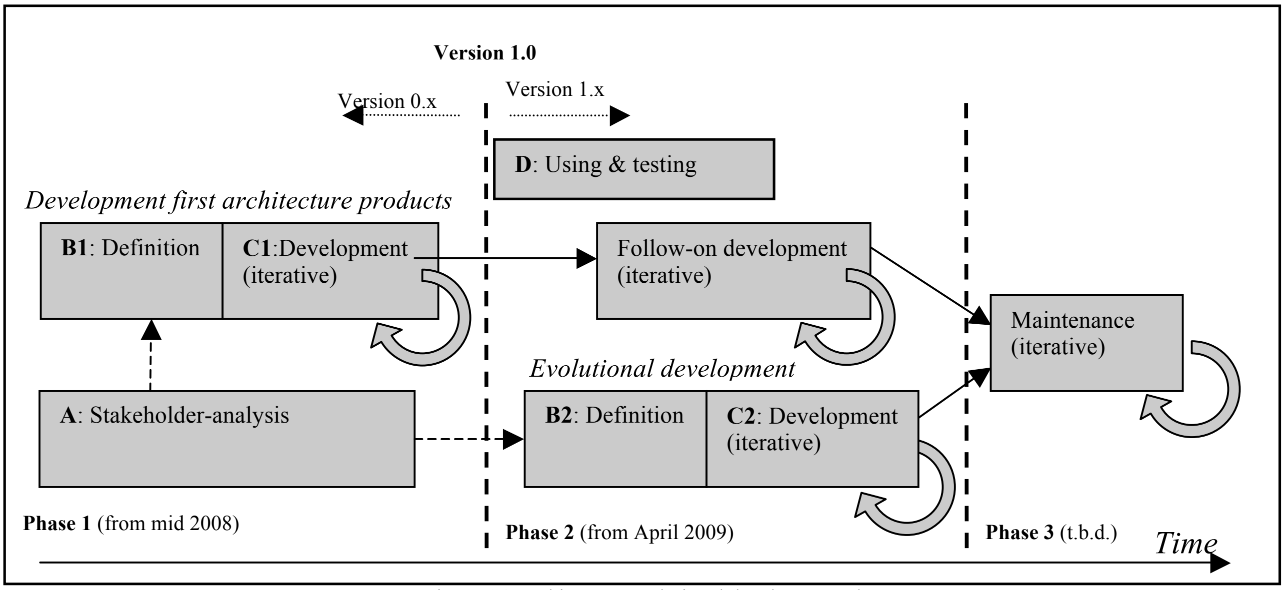

Fig. 3. C4I architecture evolutional development plan.

IV. Initial Results (1) – Stakeholder Interviews

Identifying Stakeholders

As part of the development of the Programme of Work, a series of stakeholder interviews was conducted. The primary stakeholders were identified, in consultation with Defence Staff and HDIO, and are listed in table 2, together with their interest in the C4I architecture. In addition to CDS and DIO, the following primary stakeholders were identified: the Defence Materiel Organisation (*Defensie Materieels Organisatie,* DMO) which is responsible for the management and execution of C4I projects to realise C4I requirements as stated by CDS; the Centre for Automatisation of Mission Critical Systems (CAMS), which is responsible for the development of naval C2 systems; and its army counterpart: the Command and Control Support Centre (C2SC), which is responsible for development of land-oriented C2 systems.

This would seem to leave out the development of Air Force C2 systems. A software development center for Air Force C2 systems does not exist in The Netherlands for two reasons: firstly, the Air Force is using NATO C2 systems and industrial proprietary C2 systems embedded in aircraft, which means less requirements for own C2 software development; secondly, some systems developed by C2SC are also in use by the Air Force, such as the Theatre Independent Tactical Army and Air Force Network (TITAAN), which is a deployable ICT infrastructure for deployed Army and Air Force units.

The major operational commands (maritime, land and air) are primary stakeholders as well, being the major users of C4I services and systems and as such involved in the identification of future C4I requirements. The required level of detail of the C4I architecture can thus be derived from its purpose, as viewed by its primary stakeholders.

Although not considered primary stakeholders, NATO and operational partners could also be listed as stakeholders of the C4I architecture. They have an interest in the Netherlands C4I architecture as well, since it supports cohesion and interoperability in an international environment. Finally, even the C4I industry is to some extent a stakeholder, in view of the shift to more use of Military Off The Shelve (MOTS) and Commercially Off The Shelve (COTS), and the possibility of Public Private Partnerships.

TABLE 2
PRIMARY STAKEHOLDERS AND PURPOSE OF C4I ARCHITECTURE AS VIEWED BY THEM

primary stakeholder	purpose of C4I architecture as viewed by stakeholder
CDS	the C4I architecture supports the translation of C4I policy into C4I requirements, provides cohesion and priorities between C4I requirements
HDIO	the C4I architecture complements DIVA, provides specific requirements for the mobile and deployable ICT infrastructure (HDIO's responsibility)
DMO	the C4I architecture provides guidance for C4I project architectures, specifies technical standards, provides coherence between C4I projects
CAMS & C2SC	the C4I architecture provides priorities, guidance and coherence for development of new systems and services, specifies technical standards
major operational commands	the C4I architecture provides a means to articulate information exchange requirements and insight in the realisation of these requirements

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Stakeholder Interviews

A series of structured stakeholder interviews were conducted, using the ISO-accepted Recommended Practice for Architectural Description of Software-Intensive Systems [5] (the former IEEE standard 1471) and the NAF [8] as guidelines. As in NAF, one of the interview goals was to map the Communities of Interest (CoI) to which the stakeholders belong, each CoI being a well defined area of responsibility / interest. A stakeholder can be part of various CoI's, and each CoI will require various specific views of the relevant aspects of the C4I architecture, see fig. 4.

Most of the CoI's as used in NAF were considered too high-level and not appropriate for our purpose. We defined a series of C4I-related CoI's assumed to be more appropriate, as listed in table 3, together with a description of the activities we expect to be related to these CoI's. We asked stakeholders to indicate which CoI's they considered themselves to be part of, and to indicate the related information requirements, again to be chosen from a list of standard DIVA-related terminology Apart from mapping stakeholder CoI's, we used the interviews to obtain insight into stakeholder expectations about the C4I architecture, their concerns regarding C4I, what already had been done about C4I architecture and who else should be involved. A week before a planned interview we sent the stakeholder an introduction document, including information and questions about CoI's as described above, and five other initial questions to be answered and submitted before the interview, as listed in table 4. The written answers were subsequently used as a starting point for the interviews to elaborate on, using a more detailed questionnaire.

Interview Results

The CoI mapping process worked well; stakeholders recognized the predefined CoI's and provided a detailed description of their interest. The outcome of the mapping of CoI's will be used for the development of the operational process model and the operational information services model, and to define which views will be required. For areas of interest currently not covered with the planned architecture products, additional architecture products will be defined in phase 2 of the architecture development.

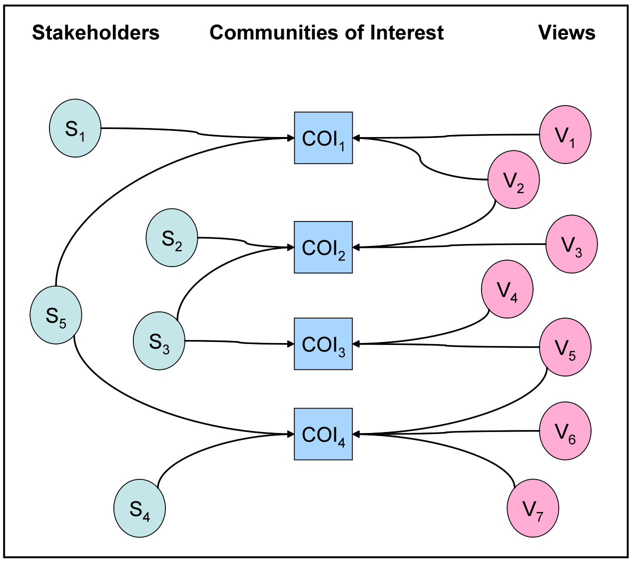

Fig. 4. Stakeholders, CoI's and Views.

TABLE 3
PREDEFINED COI'S

Non-operational CoI's	Operational CoI's
Policy / doctrine	OPS planning
Planning / budget	OPS support
Requirements	OPS security
Acquisition	C4I planning and management
Research and development	C4I maintenance
HRM	Weapon employment
	Sensor management
	ISR/INTEL
	Education and training

TABLE 4
STAKEHOLDER INTERVIEWS - INITIAL QUESTIONS

1	What is your definition of C4I?
2	What is your role in C4I?
3	What is your expectation regarding the C4I architecture?
4	Can you identify other stakeholders?
5	Are you aware of existing C4I architecture products or initiatives?

We used the questions on definition of C4I and expectations of the C4I architecture to arrive at a definition of purpose and scope of the C4I architecture which would be supported by its future users, being the stakeholders. Based on the outcome of the stakeholder interviews, the purpose of the C4I architecture was formulated as follows:

The C4I architecture should

- provide guidance for the definition of future C4I requirements;
- support better scoping of new C4I projects and relations between projects;
- provide better cohesion and integration between C4I projects;
- provide guidance for the development of C4I project architectures;
- provide standards and technical requirements for C4I projects.

With respect to the scope of the C4I architecture, the interviews made it clear that the required scope exceeded the scope as envisioned in DIVA. The C4I architecture should cover all aspects of the provision of information support to military operations. This should include other information domains such as information on operational logistics and personnel. However, information support in these areas is covered in other DIVA sub-architectures. The operational environment also poses specific requirements with respect to the agility of the supporting ICT infrastructure and the operational security. These specific requirements should also be included in the C4I architecture. However, these aspects are covered in DIVA aspect-architectures. To avoid overlap and conflict between different DIVA supporting architectures, it was decided that these aspects would be included in the scope of the C4I architecture, and that the stated requirements should be regarded as an input to other supporting architectures.

The outcome of the interviews provided information on existing C4I architecture products and activities, which could be used as a baseline for the C4I architecture development. It became clear that the Army was the only service which had in the past developed its own C4I architecture. CAMS and C2SC, being C4I system development centres, were using C4I project architectures and some generic architecture principles and guidelines, which they had developed. Based on existing architecture-related activities, agreement was reached on the stakeholder involvement in the development of C4I architecture products, as listed in paragraph 3.1. Existing architecture products would be used as much as possible.

As far as stakeholder concerns and expectations cannot be addressed with the first set of architecture products, other architecture products will be defined. These are to be developed in phase 2 of the project (see paragraph 3.2).

Finally, the stakeholder interviews provided information on other parties involved in C4I. These "secondary stakeholders" will be interviewed later. To support involvement of all stakeholders in the architecture development, a project organisation has been developed, with an information exchange mechanism using the defence intranet and Wiki technology.

V. Initial Results (2) – Process and Services Models

Examining Existing Process Model

The DIVA contains a full generic process model of all defence processes, which includes an operational process model, see fig. 5. This model was developed by TNO and HDIO some years ago [11] and should serve as the baseline for further development. However, it appeared that at the time, this model had been received in the C4I community with some reservation. The components of operational action were considered too abstract and generic. For this reason, as a first step in the development of the operational process model for the C4I architecture, the possible shortfalls of the existing DIVA operational process model were examined.

It appeared from [11] that to arrive at a generic operational process model, each of the Armed Services had been requested to describe its own generic operational process at a high level, using free form. The result was some very dissimilar and complicated graphs and descriptions. To amalgamate these into a common process had been a difficult task, which required a high level of abstraction. Another apparent shortfall was the national, service-specific focus of the process descriptions. As a result, joint and combined aspects were only marginally addressed. Others have shown that this is a common shortfall in C4I architecture development, see [4].

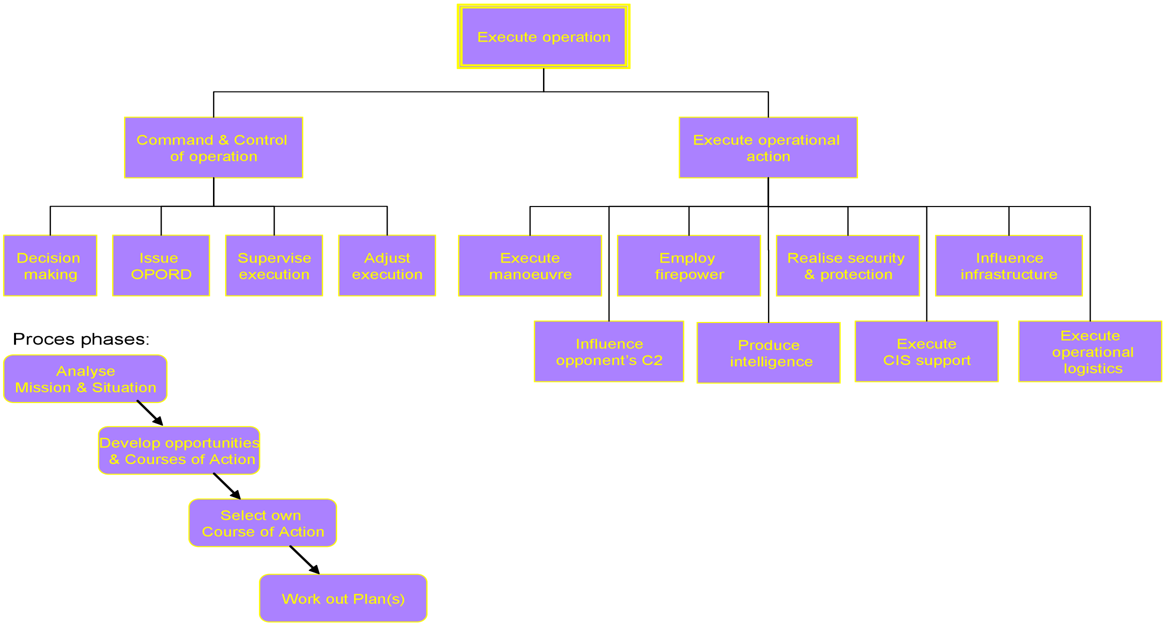

Fig. 5. DIVA operational process model.

New Process Model Development Approach

A new approach for the development of an operational process model has been developed. Separate processes for different operational activities will be modelled. The universally accepted OODA Loop as developed by Boyd will be used as the archetype of operational processes. Using this model for the development of different process models should result in models that can be compared with each other, related and combined. In this way a hierarchical operational process model could be built bottom-up.

Separate processes to be modelled initially should have the following characteristics:

- joint aspects, i.e. the possibility of participants of more than one service;
- combined aspects, i.e. at least a notional NATO and/or non-NATO participant;
- complementary, i.e. together they require the full spectrum of operational information services;
- imperfect, i.e. they have known shortfalls in their information support.

This should result in process models which address the challenges of today's operational deployments, with its requirements for agility and interoperability, as described in paragraph 1.2.

The model of each operational process should show the operational entities involved, their relations, the information required by each entity, processes performed by entities and the information flow between entities. In this way, the operational process model should provide input to the operational information services model to be developed, by showing which operational information services are required by whom.

It is envisioned that both education and training centres and operational staffs and units will be involved to obtain information for the development of operational process models. Each operational process should be developed in 6 steps, as shown in table 5.

TABLE 5
DEVELOPMENT OPERATIONAL PROCESS MODEL

step 1	Collect process information at the relevant education & training centre
step 2	Study material obtained, develop first draft process model
step 3	Collect comments from education & training centre, develop 2nd draft
step 4	Test the model by visiting operational staffs/units involved in the process to be modelled, observe process, collect information, discuss problems and requirements
step 5	Correct, refine and amplify the process model
step 6	Validate the final product with all parties involved in the process

Operational Information Services Model

The DIVA contains an operational information services model. It is derived from the DIVA operational process model, the shortfalls of which were discussed above. The development of an operational information services model for the C4I architecture will run in parallel with the development of the operational process model, from which it will be derived. In addition, a bottom-up process will be followed. With assistance from CAMS and C2SC, it will be examined how the functionalities of current and planned operational information systems can be expressed in terms of operational information services, and to what extent these services are reusable by other information systems.

Reusable, independent software services, as described in paragraph 2.5, are an important enabler for NEC, as they enhance interoperability and agility. Although DIVA mandates a service-oriented approach, the DIVA definition of services can be read as a standardised way to describe functionality. This definition of services appears to be broader that it's strict software-technical meaning as described in paragraph 2.5. This difference should be examined and articulated in the operational information services model.

VI. Lessons Learned, Further Research

Lessons Learned

Our first steps in the development of a C4I architecture for the Netherlands Armed Forces already provided us with the following lessons learned. They could be beneficial to other organisations at the same stage of architecture development.

- Get to know the architecture stakeholders early, address their concerns and involve them from the outset.
- Include non-operational information domains in the scope of the C4I architecture (personnel, logistics, ICT infrastructure), as far as they are essential for operations support.
- Include some architecture products which can be developed in a limited timescale, to show early results which are useable, and thus ensure support.
- Build an operational process model bottom-up, using a standardised way to model the operational processes, such as the OODA Loop.
- Select operational processes with joint and combined aspects as the first to be modelled, as they address today's requirements for agility and interoperability.
- Services are a popular term. Discriminate between services in general and the strict software-technical meaning of the term "software service".

Further Research

In the context of specific research for the development of process and service models, the following related research issue will be addressed:

- The suitability of methods and tools from DIVA, which are as yet only used and tested for business processes, for the modelling of operational processes and services. This should include comparison with methods and tools from other architecture frameworks such as NAF and DoDAF.

Beyond the development of the C4I architecture, the following related research issues could be addressed:

- The suitability of the C4I architecture to support the planned transition of the Netherlands Armed Forces to higher NEC maturity levels.
- The suitability of a Service-Oriented Architecture to support the information exchange between the military and its civil partners in an operation.

References

[1] *Netherlands Defence Doctrine* (*Nederlandse Defensie Doctrine)* (NDD), first edition, Netherlands Ministry of Defence (MOD NL), 2006.
[2] *NEC Action Plan (Actieplan Network Enabled Capabilities),* Netherlands NEC Steering Group (NEC Regiegroep), version 2.0, January 2008.
[3] *DoD Architecture Framework* (DoDAF), version 1.0, Vol I-III, US Department of Defense, February 2004.
[4] R. J. Curts and D.E. Campbell, *The trouble with C2 architectures,* Proceedings of 12th ICCRTS, June 2007.
[5] *Recommended Practice for Architectural Description of Software-Intensive Systems,* ANSI/IEEE standard 1471-2000, in 2007 accepted by the International Standards Organisation (ISO) JTC1 as ISO/IEC DIS 42010:2007. ANSI: American National Standards Institute, IEEE: (US) Institute of Electrical & Electronics Engineers.
[6] *The Open Group Architecture Framework* (TOGAF), developed by the Architecture Forum of The Open Group, continuously evolved since mid-90's. Current version is 8.1.1.
[7] Michael Pidwirny, *Definitions of Systems and Models*, 1999-2007.
[8] *NATO C3 System Architecture Framework* (NAF) version 2, AC/322-D(2004)0041, 2004.
[9] *Netherlands Defence Information Architecture (Defensie Informatie Voorzienings Architectuur)* (DIVA), Chief Information Officer, Netherlands Defence (Hoofd Directeur Informatie Voorziening en Organisatie, HDIO), 2004.
[10] J.M.J. Riemens et al, *Een architectuur-metamodel voor Defensie; meer samenhang en herkenbaarheid,* TNO-DV 2008 A117, January 2008.
[11] *Operational processes and information services. Input for the C4I sub-architecture of DIVA (Operationele processen en IV-services. Input voor de deelarchitectuur operatiën/C2, DIVA),* Chief Information Officer, Netherlands Defence (HDIO) & Netherlands Organisation for Applied Scientific Research (TNO), 2005.