11TH INTERNATIONAL COMMAND AND CONTROL RESEARCH AND TECHNOLOGY SYMPOSIUM

COALITION COMMAND & CONTROL IN THE NETWORKED ERA

Measuring the Potential Benefits of NCW: 9/11 as case study

Topics: C2 Experimentation; Network-Centric Metrics; Lessons Learned

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Abstract

This paper presents the detailed results of a thought experiment in Network-Centric Warfare based on the events of September 11, 2001. The focus is on civil air traffic control and military air defence over the continental United States as a complete C2 system. In the thought experiment, the C2 shortcomings in this system on September 11, 2001, are hypothetically rectified using NCW concepts. The resulting concept of operations, chain of command, and event timeline are derived by hand-simulation, and compared with the actual course of events. Conclusions are drawn on the validity of the Network-Centric Warfare value chain.

1. Introduction

Background

The four basic tenets of Network-Centric Warfare (NCW) theory [Alberts, Garstka & Stein, 1999] [Alberts & Hayes, 2003] [Alberts & Hayes, 2006] are that:

- A robustly networked force improves information sharing.
- Information sharing enhances the quality of shared situation awareness.
- Shared situation awareness enables collaboration and self-synchronisation, and enhances sustainability and speed of command.
- These in turn dramatically increase mission effectiveness.

These tenets form the *NCW value chain* (see Figure 1).

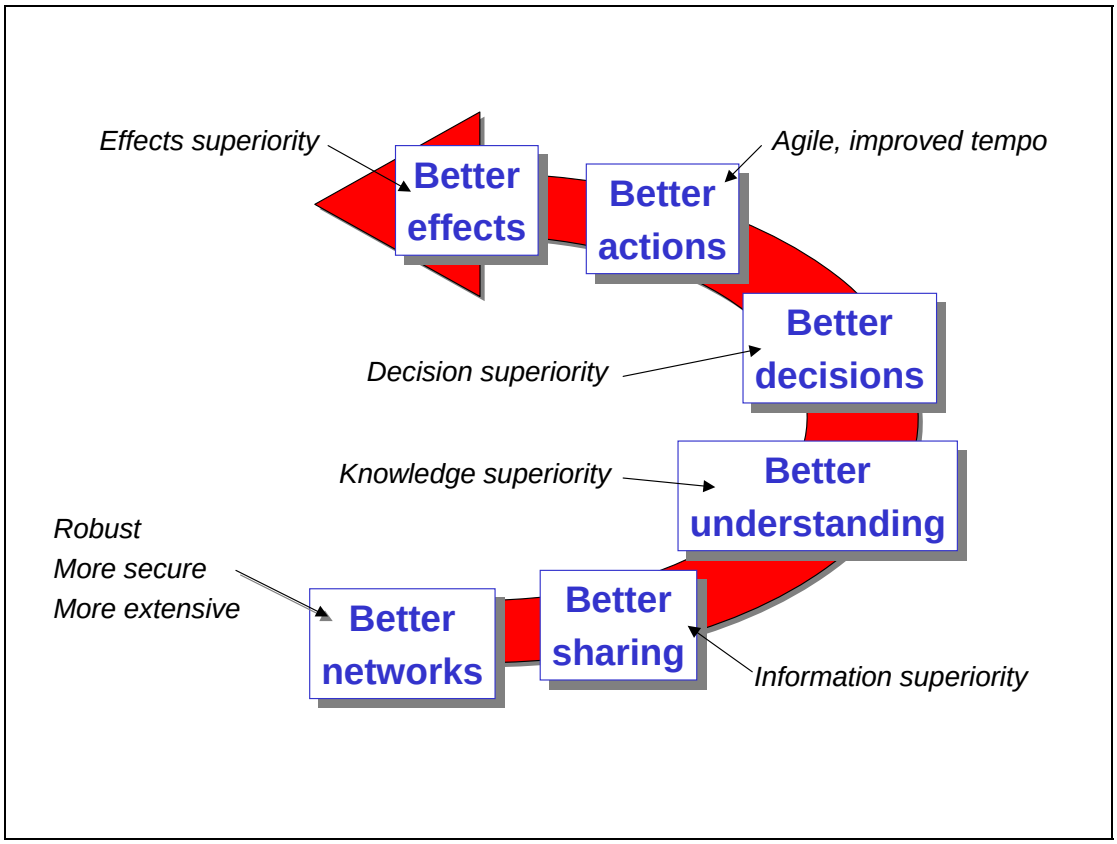

Figure 1. NCW value chain.

Demonstrations, experiments, and case studies are in hand to validate the NCW value chain. For a small country, such as The Netherlands, the investment needed to make sufficient assets net-ready for large-scale concept demonstrations and experimentation is daunting. Hence, the approach taken in the research reported in this paper is to minimise cost by performing "thought experiments". Well-documented events are sought where network-centric operation could have been beneficial. The documentation must include an event timeline because speed of command, operational tempo, and agility are key factors in NCW. The event is analysed by asking: "what if the units involved had been networked?" NCW benefits are determined by comparing the hypothetical and actual outcomes.

The events of September 11, 2001, meet the criteria for a thought experiment. Extensive documentation is available in the public domain, most notably in the form of the final report of the National Commission on Terrorism Attacks upon the United States [9/11 Commission,

2004]. A staff monograph published on the US National Archives and Records Administration (NARA) website on September 12, 2005 [9/11 Commission, 2005], gives an authoritative chronology for the four hijacked flights. Additional sources provide insight into events inside the Federal Aviation Authority (FAA) [AWST, 2001] and North American Aerospace Defense Command (NORAD) [AWST, 2002a/b] control centres and from the fighter pilots' viewpoint [AWST, 2002c].

Purpose & scope

The purpose of this paper is to present the detailed results of a thought experiment intended to confirm the NCW value chain. The experiment is based on the events of September 11, 2001. The focus is on civil air traffic control and military air defence over the continental United States (CONUS) as a complete C2 system, including the operation of this system. Other aspects of the events (e.g. intelligence breakdown, inadequate airport security, unprotected cockpits, and rescue at Ground Zero) and the NCW issues of doctrine, procedures, organisation, training, leadership, culture, and implementation are outside the scope of the paper.

Structure

This paper consists of six sections. Section 1 is introductory. Section 2 summarises the FAA's and NORAD's concepts of operations prior to September 11, 2001. Section 3 extracts the relevant events, with timings, from the source documents, and discusses situation awareness and sensemaking on September 11, 2001. Section 4 identifies the C2 shortcomings. Section 5 performs the thought experiment, in which the shortcomings are rectified using NCW concepts, and describes the resulting hypothetical concept of operations, chain of command, and timeline. Section 6 draws conclusions and makes recommendations.

2. FAA and NORAD ConOps

Concepts of operation

On September 11, 2001, the FAA was responsible for civil air traffic control over the CONUS, and NORAD was responsible for military air defence.

US law mandated the FAA to regulate the safety and security of civil aviation [9/11 Commission, 2004]. From an air traffic controller's perspective, that meant maintaining separation (i.e. a safe distance) between aircraft. Operationally, the FAA was organised into 22 Air Route Traffic Control Centers, grouped under regional offices. These Control Centers coordinated closely with the overall Air Traffic Control System Command Center (SCC), located in Herndon, Virginia (nearby Washington's Dulles International Airport); see Figure 2. The SCC oversaw the daily traffic flow within the entire National Airspace System (NAS), and was primarily concerned with the nation-wide effects of severe weather or airport congestion. The Operations Center in FAA Headquarters in Washington DC received notifications of incidents, including accidents and hijackings.

In addition to the SCC, the Control Centers at Boston, New York, Cleveland, and Indianapolis were directly involved in the events of September 11, 2001. FAA Control Centers often receive information and make operational decisions independently of one another. Each center thus had part of the knowledge of what was going on across the system.

Figure 2. FAA's System Command Center.

Controllers track aircraft by watching the data from Secondary Surveillance Radar (SSR). When the aircraft is "painted" by radar, an on-board SSR transponder emits a signal that includes data concerning the aircraft's flight number, intended destination, height, speed, and heading. This data is displayed to the controllers in the FAA Control Center. If the SSR transponder fails or is switched off, the FAA controllers have to fallback onto primary radar data, i.e. "blips" on their display screens that lack the additional data. An aircraft can then only be identified if it continues to follow its pre-notified route or responds to ATC radio messages. FAA controllers have standard operating procedures for transponder failure, for diversion from the flight plan, for radio failure, and for hijacking, but not for a combination. On September 11, 2001, the hijackers switched off their SSR transponders, diverted dramatically from the flight plan, and - with one key exception - maintained radio silence.

NORAD was a combined command established in 1958 between Canada and the United States [9/11 Commission, 2004]. Its mission was to defend the airspace of Northern America. Since NORAD was created to counter the Soviet threat, it saw its job as defending the continent against external attack, e.g. by ballistic and cruise missiles or by manned bombers. NORAD's radars were located around the perimeter of the CONUS, mainly looking outwards.

NORAD was divided into three sectors. On September 11, 2001, all the hijacked aircraft were in NORAD's Northeast Air Defense Sector (NEADS), based in Rome, New York. NEADS reported to the Continental US NORAD Region (CONR) headquarters, located in Florida, which in turn reported to NORAD headquarters in Colorado Springs. That morning, NEADS could call on two alert sites, each with one pair of ready fighters: two F.15 fighters at Otis Air National Guard Base (ANGB) in Cape Cod, Massachusetts, and two F.16 fighters at Langley Air Force Base (AFB) in Hampton, Virginia.

Procedures

Prior to September 11, 2001, the FAA and NORAD had developed procedures for working together in the event of a hijacking [9/11 Commission, 2004]. The procedures required multiple levels of notification and approval at the highest levels of government. An order to

shoot down a commercial aircraft would have had to be issued by the National Command Authority (a phrase used to describe the US President and US Secretary of Defense).

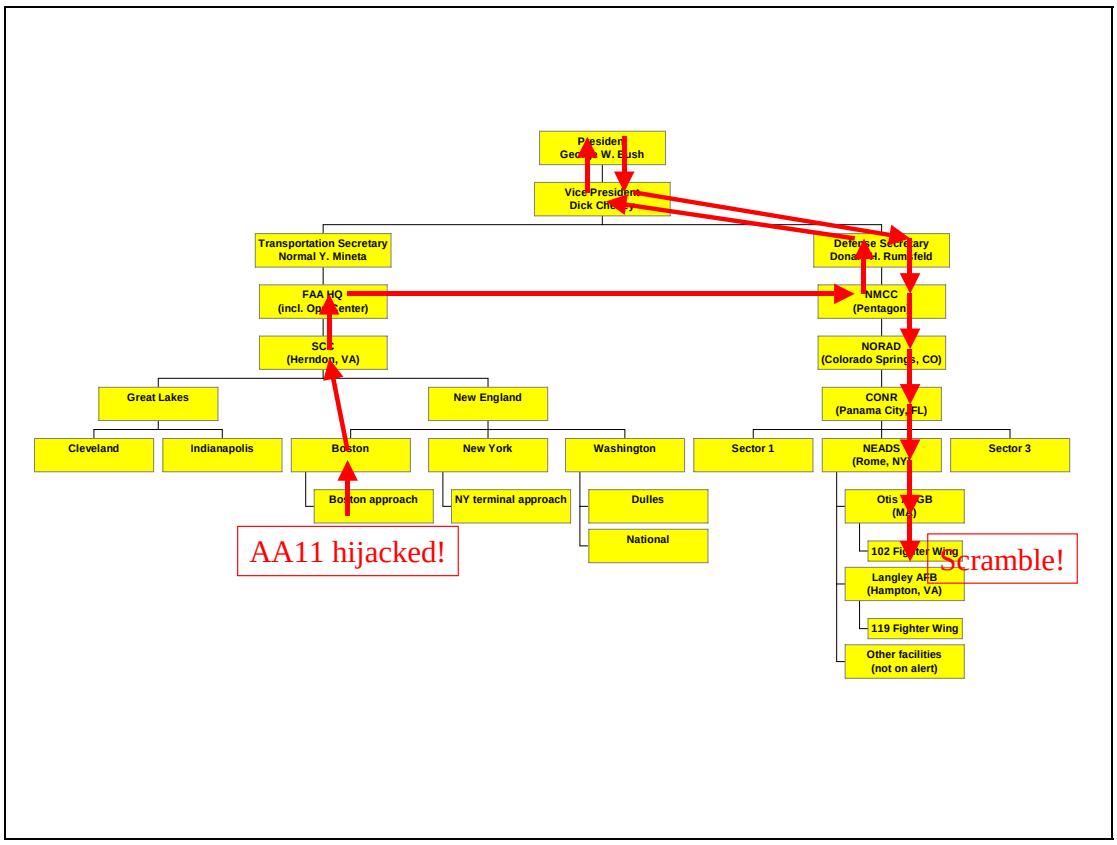

Figure 3. Chain of command, as procedures said it should have happened.

FAA guidance to controllers on hijack procedures assumed that the aircraft pilot would notify the controller by radio or by switching to the transponder code for a hijack in progress. Controllers would notify their supervisors, who would in turn notify management all the way up to FAA headquarters in Washington. If a hijack was confirmed, procedures called for the hijack coordinator at FAA headquarters to contact the National Military Command Center (NMCC) at the Pentagon. The NMCC would then seek approval from the Office of the Secretary of Defense to provide military assistance. If approval were given, the orders would be transmitted down NORAD's chain of command to the fighter pilots on alert. Figure 3 shows the organisational hierarchy and chain of command (as called for by the procedures), derived from the source material [9/11 Commission, 2004]. Note that the chain of command largely followed the organisational hierarchy.

Military assistance would normally take the form of providing an aircraft to escort the hijacked aircraft, to report anything unusual, and to aid search and rescue in emergency. Because the FAA and NORAD control systems were not interoperable, the relevant FAA control centre would relay tracking information to NORAD to vector the military aircraft to a position five miles behind the hijacked aircraft. Every attempt would be made to have the hijacked aircraft switch to the hijack-in-progress transponder code so that it would become visible to NORAD. In short, the procedures assumed that:

- The hijacked aircraft would be readily identifiable and would not attempt to disappear;
- There would be time to handle the problem through the appropriate FAA and NORAD chains of command; and
- The hijacking would take the traditional form, i.e. it would not be a suicide mission.

On September 11, 2001, the FAA and NORAD were lucky in the sense that Exercise Vigilant Guardian was in progress [AWST, 2002a]. More fighters and airbases were on alert than usual. Officers involved in Vigilant Guardian were manning NORAD command centres throughout the US and Canada. The military liaison cell within the FAA's SCC was manned, enabling the speedy relay of tracking information to NORAD.

3. Chronology

Sources

There is an overwhelming wealth of information in the public domain on the events of September 11, 2001. For the purposes of the thought experiment, it was necessary to be rigorously selective. Only material relevant to the civil air traffic and military air defence aspects of the events on September 11, 2001, was sought. Even so, a choice had to be made. The following sources have been consulted in the research reported in this paper (in decreasing order of precedence):

1. The latest version of the declassified 9/11 Commission staff report on chronology and tactics published by the US Government National Archives [9/11 Commission, 2005].
2. The notes to Chapter 1 of the 9/11 Commission report [9/11 Commission, 2004].
3. Chapter 1 of the 9/11 Commission report [9/11 Commission, 2004].
4. The three-part special report by Aviation Week & Space Technology [AWST, 2002a/b/c], as well as an initial report of the events within the SCC [AWST, 2001]. These articles were included because they documented detailed, first-person interviews of events as seen from within the SCC [AWST, 2001] and NEADS [AWST, 2002a], and as seen by fighter pilots [AWST, 2002c]. In addition, a report on subsequent changes made in the SCC and NORAD [AWST, 2002b] highlights the system shortcomings on September 11, 2001.

Other sources (e.g. [CNN, 2001] [Cummings, 2001] [Time-Herald, 2001]) were excluded.

Analysis involved drawing up a chronology of events from the selected sources. Cross-checking disclosed only three minor inconsistencies, none of which had any influence on the results. The chronology took the form of a two-dimensional matrix in a spreadsheet, with each event on a row and each actor on a column. Events were time-points, ordered according to the actual time of occurrence. Actors were grouped together by type (e.g. aircraft, control centre, person, etc). The emphasis was on communication events, with the cell in the originator's column marked "sender" and the cell in the recipients' column(s) marked "recipient". Occurrences with substantial duration (e.g. F.16s holding over Long Island) were represented as two point-events, one at the start and another at the end.

Relevant events

It was immediately apparent from the source material that the actual chain of command on September 11, 2001, differed significantly from that called for by the procedures. Firstly, information was broadcast via the public media[1]. Secondly, individuals within FAA's Boston approach and air route traffic control centres used their informal networks to inform military acquaintances in NEADS and at Otis ANGB, shortcutting the formal procedure [AWST, 2002a]; see Figure 4. Thirdly, military officials in NEADS and NORAD took the initiative to originate orders before they had obtained approval from their superiors [AWST, 2002a]. The outcome was that the Otis fighters were airborne earlier than they would have been if the procedure had been followed meticulously.

[1] In effect, this is a form of network-centric information sharing.

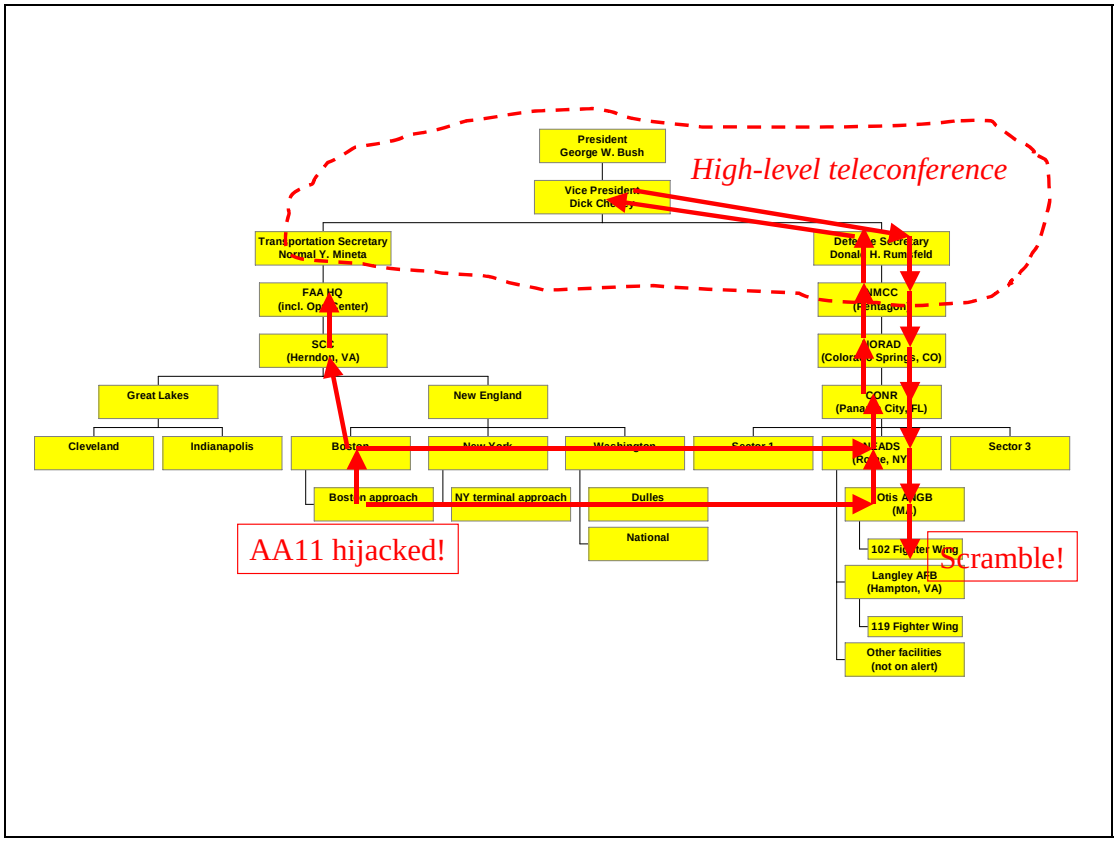

Figure 4. Chain of command, as it actually happened.

For the purpose of this analysis, we extracted relevant events from the master chronology. We are concerned with a limited subset of actors, each with a limited subset of events, as follows:

- Airliners: event-types = {hijacked; crashed}.
- FAA air route traffic control centres (i.e. excluding SCC): event-types = {aware of hijack; originate hijack report to NEADS}.
- NEADS: event-types = {originate battle stations order; originate scramble order}.
- Fighters: event-types = {receive battle stations order; receive scramble order; takeoff; overhead New York/Washington}.

The extracted events are listed below:

Time	Actor	Event
08:14	AA11	believe hijacking began at 8:14 or shortly thereafter
08:24	AA11	hijackers broadcast on ATC frequency: "We have some planes"
08:25	Boston	aware AA11 hijacked
08:37	Boston	notifies NEADS of hijacking
08:37	NEADS	orders Otis to place F-15s at battle stations
08:42	UA175	believe hijacking between 8:42 and 8:46
08:46	AA11	crashes into WTC North Tower at 8:46:40
08:46	F-15s	scrambled
08:51	AA77	hijacking began between 8:51 and 8:54
08:53	F-15s	F-15s airborne from Otis
08:55	New York	controller tells manager that UA175 hijacked
09:03	UA175	crashes into WTC South Tower at 09:03:11
09:03	New York	informs NEADS of second hijacking
09:09	F-15s	in holding pattern off Long Island
09:09	NEADS	orders Langley F-16s to battle stations
09:13	F-15s	leave holding pattern & head for NYC

09:20	Indianapolis	learns of other hijacked aircraft & doubts AA77 has crashed. Informs SCC
09:24	NEADS	orders Langley F-16s to scramble
09:25	F-15s	overhead NYC
09:28	UA93	Hijacked
09:30	F-16s	Langley fighters airborne
09:32	Cleveland	notifies SCC of UA93 hijacking
09:34	Indianapolis?	advises NEADS that AA77 is missing
09:36	NEADS	instructs F-16s to head supersonic for White House (150 miles away)
09:37	AA77	crashes into Pentagon at 09:37:46
10:03	UA93	crashes into Shanksville PA at 10:03:11
10:07	F-16s	overhead Washington
10:07	Cleveland	military liaison informs NEADS about UA93 hijacking
10:10	NEADS	instructs F-16s "negative clearance to shoot" over Washington

The amount of notice that the military air defence organisation had of each hijacking is shown in Figure 5. The figures have been calculated by subtracting the time at which NEADS was informed that the airliner had been hijacked from the time at which the airliner crashed. For example, AA11 crashed at 08:46 and FAA Boston informed NEADS at 08:37 that AA11 had been hijacked, yielding nine minutes notice.

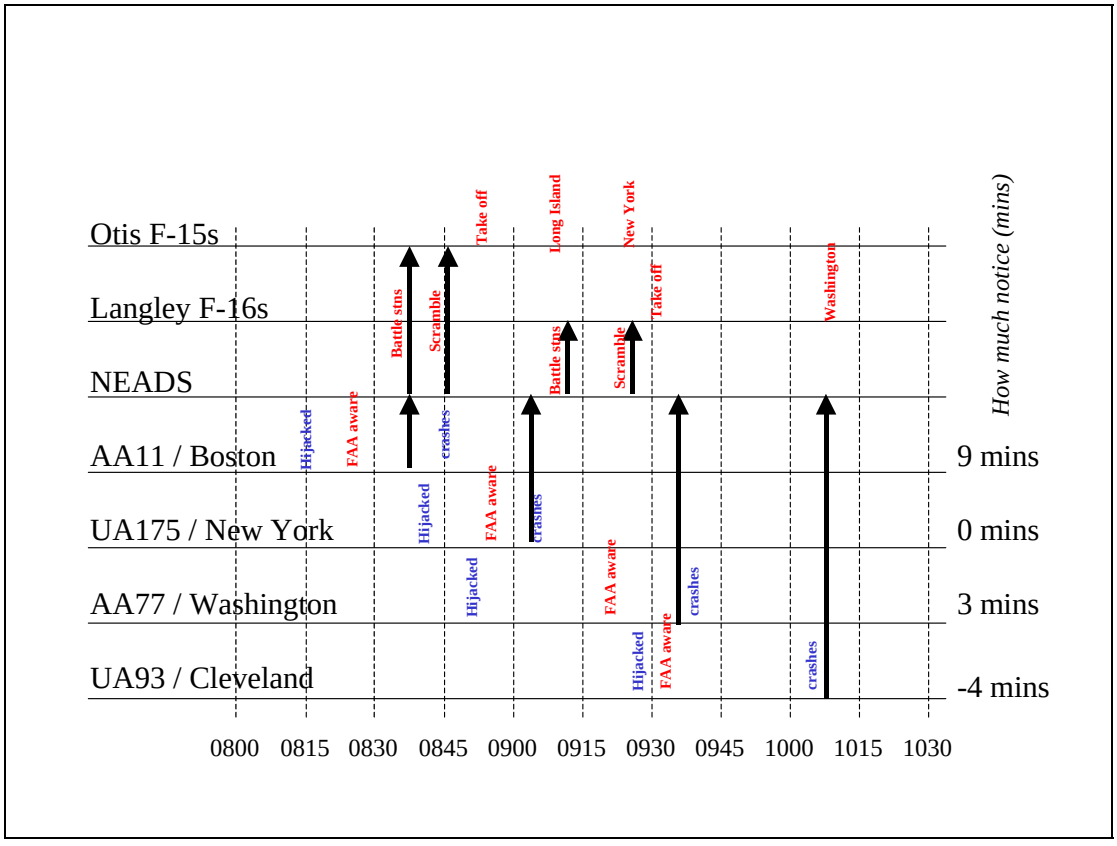

Figure 5. Actual timeline.

To shoot down an airliner, the amount of notice would have had to be sufficient for:

- NEADS to obtain National Command Authority. On September 11, 2001, this step cost zero minutes because NEADS took the initiative to obtain authorisation *post-hoc*.
- NEADS to issue orders to the fighters. From the source material, it is apparent that it took the fighters about 6 minutes to go from battle stations and another 6 minutes to take off after receiving the order to scramble.

- The fighters to reach the target area. Otis' F.15s were overhead New York 32 minutes after takeoff, and Langley's F-16s were overhead Washington 37 minutes after takeoff[2].

As the 9/11 Commission Report concludes [9/11 Commission, 2004], there was insufficient notice to have shot down any of the airliners hijacked on September 11, 2001.

4. C2 Shortcomings

There were several shortcomings in command and control (C2) within the civil air traffic and military air defence system on September 11, 2001. The key shortcomings were:

- *Strategic surprise*. Al Qaeda achieved strategic surprise on September 11, 2001. The civil air traffic and military air defence system did not have the shared mission to detect and respond to a suicide hijacking [9/11 Commission, 2004].
- *Command and reporting chain*. The FAA/NORAD procedures on September 11, 2001, were based on Cold War assumptions. In particular, they assumed that there would be sufficient time to communicate multiple levels up and down a hierarchical command / reporting chain to obtain shoot-down approval from the National Command Authority [9/11 Commission, 2004]. Even with the shortcuts taken on September 11, 2001, by exploiting informal networks and by employing individual initiative, there was insufficient time to shoot down any of the hijacked airliners.
- *Human error*. There were errors made on September 11, 2001. For example, FAA headquarters were informed of the hijacks in progress, but did not obtain military assistance from the Pentagon, as the established procedure required [9/11 Commission, 2004].
- *Technical problems*. There was no interoperability between the FAA and NORAD C2 systems on September 11, 2001 [AWST, 2002a]. It was assumed that placing military liaison officers in the FAA control centres was sufficient to ensure adequate civil-military communication. The lack of interoperability can be regarded as a consequence of the lack of a shared mission to detect and respond to a suicide hijacking.

Luckily, Al Qaeda also exhibited shortcomings on September 11, 2001. In particular, the hijackers on AA11 and UA93 broadcast on ATC radio frequencies messages that were intended only for the passengers and crew of the hijacked airliners [9/11 Commission, 2004]. The most dramatic of these occurred at 08:24 when a hijacker on AA11 broadcast the sentence: "We have some planes", implying that multiple hijackings were in progress. An alert controller in the FAA Boston control centre heard this, took action to confirm what he had heard[3], and warned his chain of command. Unfortunately, there was no mechanism in place to exploit fully this key piece of knowledge. In the thought experiment, we provide a suitable mechanism: a network.

5. Using NCW to Rectify Shortcomings

Assumptions

We assume that, on September 11, 2001, all the key actors in the civil air traffic and military air defence system were linked by a hypothetical *hijack network*. For the purposes of the experiment, we assume that these key actors were the FAA's air route traffic control centers, NEADS and NORAD. The precise nature of the hijack network is unimportant. It could be implemented as a chat / messaging channel, a weblog, a webpage, a shared database, etc. The actual implementation adopted immediately following September 11, 2001, was an always-

[2] However, both pairs of fighters took a roundabout route.
[3] This is a clear example of sensemaking, complying with all the hallmarks listed in [Weick, 1995].

open conference call linking the FAA's air route traffic control centres, the SCC, federal security offices, the US Customs Service, NORAD, and "a number of other control centers" [AWST, 2002b].

We also assume that:

- All actors were net-ready and fully trained in the use of the hijack network;
- The procedure for responding to a hijack made full use of the hijack network;
- NORAD again took the initiative to issue orders in advance of shoot-down approval;
- The FAA Boston controller broadcast on the hijack network what he heard at 08:24;
- NEADS issued the battle stations order to Langley as soon as it was known (in FAA New York) that a second airliner had been hijacked, giving hard confirmation of the 08:24 "We have some planes" message; and
- The times taken to go to battle stations, to takeoff, and to transit to the target area were all unchanged.

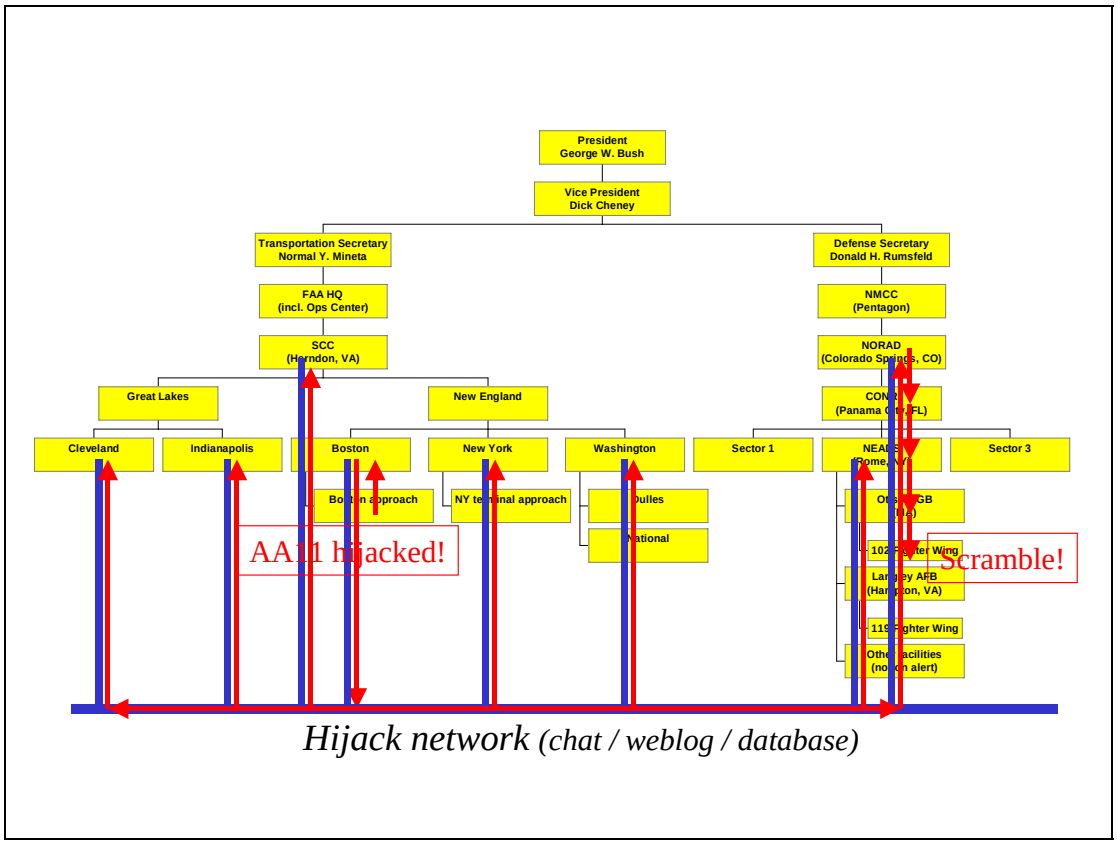

Figure 6. Hypothetical chain of command, assuming network-centric operation.

Concept of operations with NCW

The upshot of network-centric operations is that the chain of command is no longer constrained to follow the organisational hierarchy. The introduction of a network enables communications to take a more direct line from "sensors" to "shooters". This is depicted in Figure 6 by superposing the hijack network on the (unchanged) organisational hierarchy. As soon as Boston approach informs the Boston air route traffic control center the information is placed on the hijack network, where it immediately becomes available to the other air route traffic control centers, NEADS, and NORAD. While NORAD is giving approval to shoot down a commercial airliner, NEADS is allocating the fighter resources to do so.

Timeline

Based on the (hypothetical) network-centric concept of operations, the timings of the orders issued by NEADS can be adjusted forwards. For example, NEADS would have learned of AA11's hijacking at 08:25 instead of 08:37, a gain of 12 minutes notice. Since NEADS ordered Otis to placed its F-15s to battle stations immediately on receiving the information that AA11 had been hijacked, the order would have been issued 12 minutes earlier. All other F-15-related events (scramble, takeoff, arrival over New York) can also be brought forward by 12 minutes.

A similar argument applies to Langley's F-16s. They were ordered to battle stations once NEADS had been informed of UA175's hijacking. Under the assumed network-centric concept of operations, NEADS would have learned of this at 08:55, a gain of eight minutes notice. All dependent events relating to the F-16s can be brought forward by eight minutes.

The following table shows the hypothetical course of events, with the changes in highlighted italics:

Time	**Actor**	**Event**
08:14	AA11	believe hijacking began at 8:14 or shortly thereafter
08:24	AA11	hijackers broadcast on ATC frequency: "We have some planes"
08:25	Boston	aware AA11 hijacked – *broadcast over network*
08:25	NEADS	orders Otis to place F-15s at battle stations
08:34	F-15s	scrambled
08:41	F-15s	F-15s airborne from Otis
08:42	UA175	believe hijacking between 8:42 and 8:46
08:46	AA11	crashes into WTC North Tower at 8:46:40
08:51	AA77	hijacking began between 8:51 and 8:54
08:55	New York	controller tells manager that UA175 hijacked – *broadcast over network*
08:57	F-15s	in holding pattern off Long Island
09:01	NEADS	orders Langley F-16s to battle stations
09:01	F-15s	leave holding pattern & head for NYC
09:03	UA175	crashes into WTC South Tower at 09:03:11
09:13	F-15s	overhead NYC
09:16	NEADS	orders Langley F-16s to scramble
09:20	Indianapolis	learns of other hijacked aircraft & doubts AA77 has crashed. Informs SCC – *broadcast over network*
09:22	F-16s	Langley fighters airborne
09:28	NEADS	instructs F-16s to head supersonic for White House
09:28	UA93	Hijacked
09:32	Cleveland	notifies SCC of UA93 hijacking – *broadcast over network*
09:37	AA77	crashes into Pentagon at 09:37:46
09:59	F-16s	overhead Washington
10:03	UA93	crashes into Shanksville PA at 10:03:11
10:10	NEADS	instructs F-16s "negative clearance to shoot" over Washington

Figure 7 shows the hypothetical timeline assuming network-centric operations. This shows that the amount of notice that NEADS would have had increases from 9, 0, 3, and –4 minutes to 21, 8, 17, and 31 minutes. It is clear that:

- There would not have been sufficient time to engage AA11, UA175, or AA77.
- If UA93 had reached Washington there would have been time to engage it.

Otis' F-15s and Langley's F-16s were not sent directly to the right location because the NEADS controllers did not know what the hijackers' targets were. The F-15s were initially directed to a holding pattern off Long Island, where they stayed for four minutes until they were re-directed to New York City. Similarly, the F-16s were scrambled to Baltimore, but

headed east, and only later re-directed to the White House. It is conceivable that, as well as alerting the controllers earlier, the hijack network would have enabled the controllers to become aware more quickly of the intended targets from tracking information provided by the FAA air route traffic control centers. The controllers may then have been able to position the fighters more effectively to engage AA77 and possibly UA175.

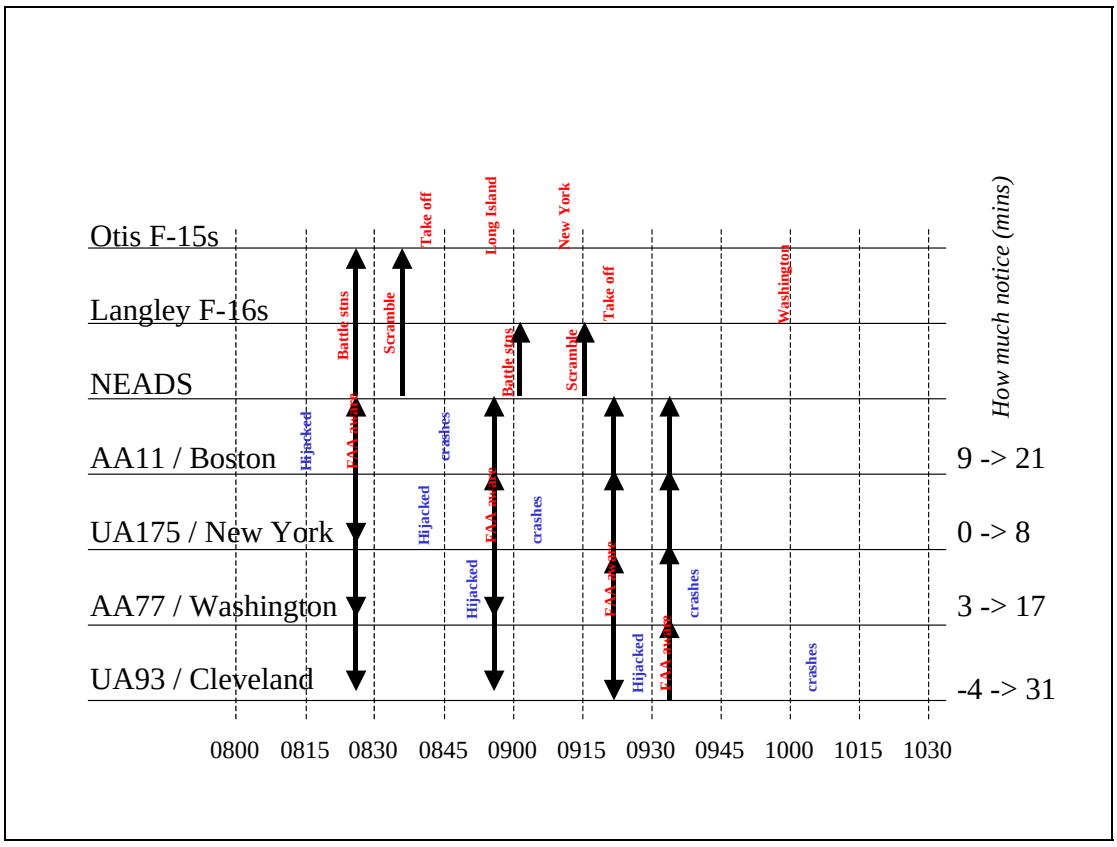

Figure 7. Hypothetical timeline, assuming network-centric operation.

In this thought experiment the information available in the public domain only allows us to draw conclusions about the times when NEADS was notified about each hijack. More detailed information is needed to draw conclusions about the quality of the shared situation awareness and decision-making that could have been reached through network-centric operations. We believe that it is noteworthy that, with network-centric operations, all the key FAA and NORAD control centers would have been aware from the outset that they were facing a multiple hijacking, thanks to the hijackers' broadcast of "We have some planes" at 08:24. We can only speculate on whether this would have enabled them to wrest the initiative from the hijackers.

6. Conclusions and Recommendations

Conclusions

In the thought experiment reported in this paper, we have shown that the availability of a network linking the civil air traffic and military air defence control centres would have changed the course of events on September 11, 2001. The network enables the command chain to short-circuit the organisational hierarchy. More specifically, hand-simulation shows that the amount of notice available to NEADS on September 11, 2001, would have increased from 9, 0, 3, and –4 minutes to 21, 8, 17, and 31 minutes. This would have enabled NEADS

to launch Otis' and Langley's fighters earlier. Given the same transit times, there would not have been sufficient time to engage AA11, UA175, or AA77. However, it seems reasonable from our analysis to expect that the longer notice would have allowed the fighters over Washington to engage UA93 in time, had the passengers not stormed the cockpit.

It is conceivable that, with the benefit of tracking information provided by the FAA air route traffic control centers over a hijack network, the NEADS controllers would have been able to position the fighters more effectively to engage UA175 and AA77. The information available in the public domain is insufficiently detailed to confirm this.

In short, this thought experiment has shown that the availability of a (hypothetical) network linking the civil air traffic and military air defence control centres would have enabled better sharing of information. This confirms the first NCW tenet. In respect of UA93 at least, it is reasonable to expect that this would have led to better military effects.

There is insufficient information in the public domain to draw clear conclusions about the effects with respect to UA175 and AA77. Hence, we are unable to draw conclusions about the second, third and fourth NCW tenets.

We also conclude that thought experiments have a role to play in NCW as they require less time and resources than full-scale demonstrations and experiments. However, the effectiveness of thought experiments depends on detailed information being available.

Recommendations

We make several recommendations:

- The Netherlands Defence Academy should develop a multi-actor simulator of the events on September 11, 2001, designed to investigate a variety of possible command chains. The simulated actors could have an internal structure based on the rationally reconstructed OODA model [Grant & Kooter, 2005] [Grant, 2005].
- The effect of a hijack network on the quality of the NEADS controllers' situation awareness and decision-making on September 11, 2001, should be investigated in more detail. Additional information is needed beyond that currently available in the public domain. Such an investigation should be designed to test the second and third NCW tenets.
- The Netherlands Defence Academy should seek other sets of events that could be used as thought experiments in NCW.

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