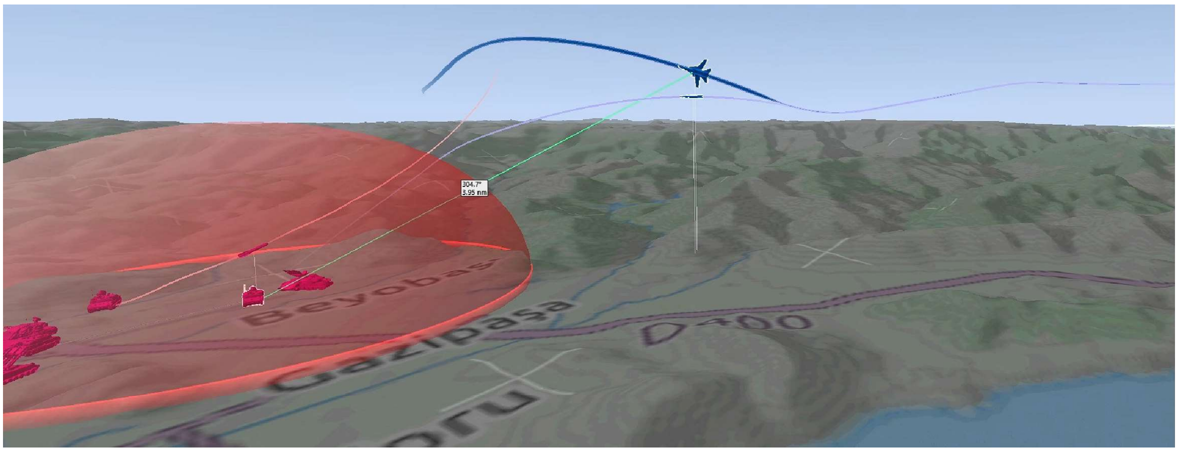

Figure 492: Tacview - Toss.

Despite the poor induced momentum, comparing the "should-have-been" ballistic trajectory at the point of release, versus the toss shows the energy advantage of the latter. This is clearly visible in Figure 492.

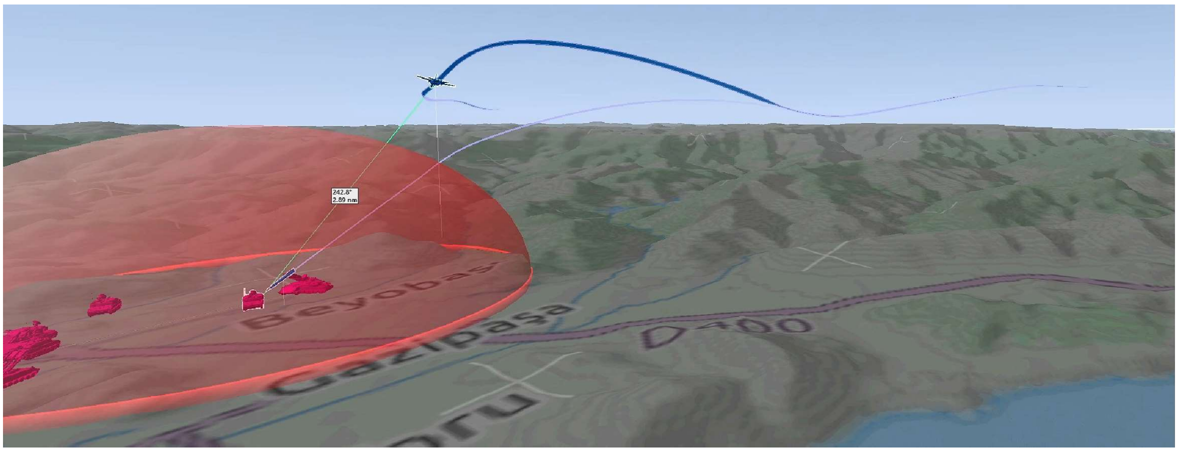

Figure 493: Tacview - Self-Lasing and impact.

Figure 493 shows the final part of the engagement, with the F-14 turning away whilst self-lasing the GBU onto its target.

Note the “bend” in the GBU trajectory as it picked the laser from the F-14’s LANTIRN pod. A potential issue of this delivery is the energy of the weapon. When it spots and guides onto the target, it loses energy. Unfortunately, the TTI indicator on the LANTIRN is not capable of taking into account the toss; thus it is not a reliable means of measuring when the laser should be activated.

17.4.8 SELF-LASED OVER-THE-SHOULDER BOMBING

This technique is… peculiar, so I did not conduct any test, but I have found someone crazy enough to actually do it.
Figure 494 and 495 show TacView screenshots of a test flown by Brody Zachary, of Digital

Coalition Air Force. It depicts a mind-blowing self-lased over-the-shoulder bombing that nailed the intended target.

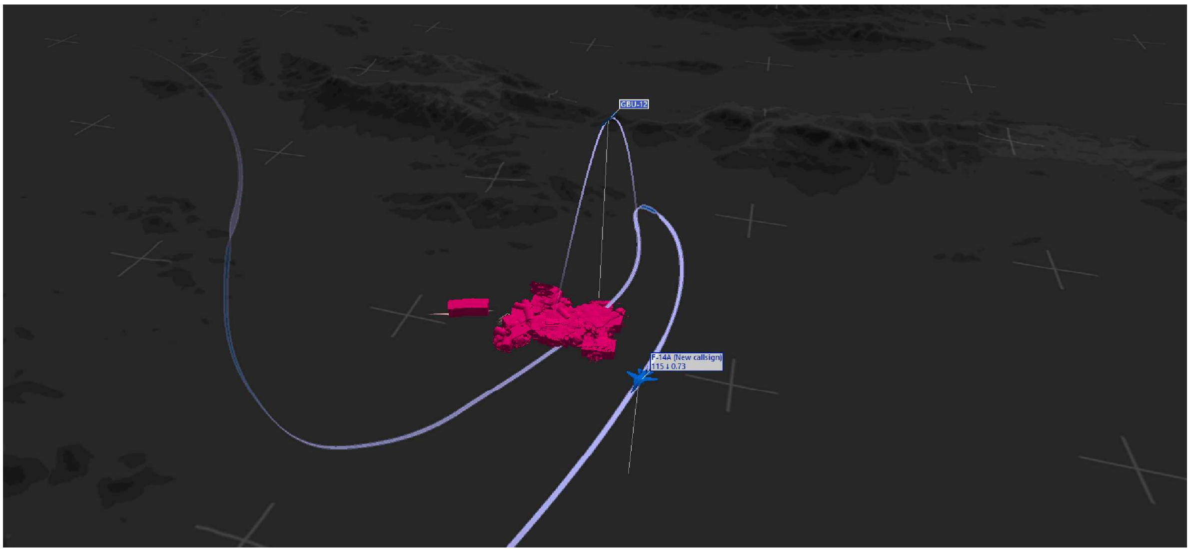

Figure 494: Brody's self-lased over-the-shoulder-bombing.

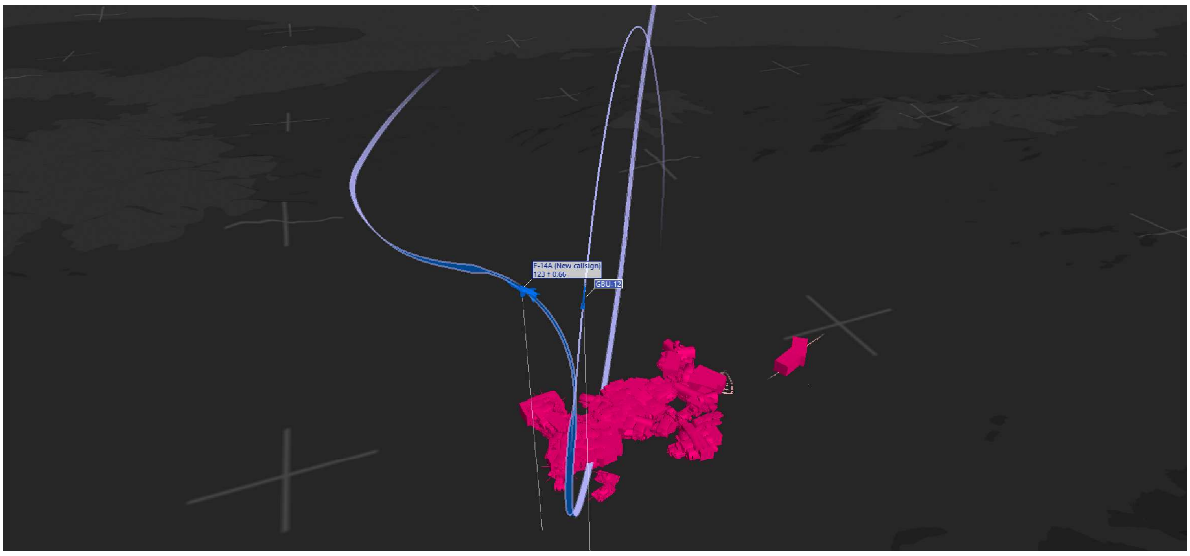

Figure 495: Brody's self-lased over-the-shoulder-bombing.

The awesomeness of this example is a good testament of the fact that there are people more nerd then me around :)

17.5 CONCLUSIONS

The F-14 is a surprisingly good air-to-ground platform, thanks to Grumman's foresight.

The technique to release ordnance depend on several factors, in primis the required accuracy and the presence and type of enemy air defences: flying closer to the ground make the fighter a harder target for medium/high SAMs, but the lower altitude expose it to AAA and MANPADs.

The precision required dictates the technique: a dive release grants a steeper impact angle, usually resulting in a much higher precision than other methods. On the opposite side, the low-level toss delivery and the dive toss provide shallower impact angles, less precise, and potentially causing more unwanted collateral damages.

In fact, if the maximum precision is necessary, the crew may be forces to opt for laser guided bombs, either self-lased, or guided by a capable airborne or ground asset ("buddy-lasing").

Besides these considerations, two points are immediately evident:

- practice is required: no matter the technique used, any non-guided delivery requires good understanding of the effects and the mechanics of the engagement.
- DCS AI: the AI tends to be way too precise and reactive and are capable of engaging with almost no warning with deadly precision. Looking at you, BMP2!

18. NAVIGATION I: BASIC CONCEPTS

18.1 INTRODUCTION

The idea of driving between two points on a perfectly straight road sounds easy: besides the human error (and the fact that a perfectly straight road must be terribly boring), there aren't many external factors that can affect the journey. Bad weather or cold can indeed pose a safety hazard, but besides catastrophic situations, they can be ignored in this scenario.
When the wheels are not glued to the asphalt, but are part of the undercarriage of an aircraft, the scenario changes. A lot. The road does not delimit our path any more, bad weather and temperature changes are a serious concern and affects visibility but also the avionics. All this factor impact the time schedule and the fuel consumption, and must be taken into consideration. Heck, even planet Earth itself can become a source of confusion.

The first chapters of this book introduced a short set of basic notions, useful to increase aviation common knowledge, and to be able to take on the challenges of flying an older virtual aircraft.
The subsequent chapters apply these concepts to a more concrete scenario, introducing the pilot to more complex situations.

18.1.1 SOURCES AND OBJECTIVES

Some of the basic topics related to flight and navigation have been introduced in the first few chapters of this book, in particular in Chapter 2.
This chapter expands those topics, adding more details and explaining the relations that often intercourse between the different concepts.

The sources used vary:

- PPL material;
- Former crews accounts (RAF and US Navy Navs and RIOs:);

- Other sources: CNATRA documentation or books such as "*Observers and Navigators: And Other Non-Pilot Aircrew in the RFC, RNAS and RAF*" by C. G. Jefford.

The objective is conveying the basic concepts of navigation, why understanding them is important, all within the environment of DCS.
However, this is just a drop in the ocean, if the topic fascinates you, I thoroughly suggest to go deeper on your own.

18.2 EFFECTS OF WIND

> *Winds varied tremendously in both direction and amplitude at different altitudes; on the ground, winds might be as slight as 5 knots, while at 15,000 feet they might be coming from the opposite direction at 100 knots.*
> *[...] The slim chance of hitting the target with "dumb" bombs in a strong wind at high altitude could only be compensated for by dropping many of them.*
>
> **ANGLES OF ATTACK, AN A-6 INTRUDER PILOT'S WAR (P. 242-243).**

The impact the wind has on a flying object is something most of us witnessed as kids: ultra-light football, windy day, trying to pass to a far teammate, you kick the ball just to see it change its trajectory in a direction closer and closer to the direction of wind. If not backwards entirely.

Something similar happens to aircraft as well, although usually, they are not blown away entirely for several reasons: for instance, in such conditions planes are diverted or are grounded, and aircraft have a propelling system (although, sometimes, you can see hilarious stuff over the internet).

Any flying object is subject to the movement of the surrounding air, and the movement of the air relative to ground is called *Wind Speed* or *Wind Velocity*.

Note: that the two terms have different meanings depending on the context, but for the purpose of this book they are interchangeable. However, when considered as a vector, Wind Velocity (indicated as "*W/V*") is more appropriate, since it implies a direction, on top of the rate of movement.

The wind de facto pushes the aircraft following its direction. The resulting "real movement" (represented by TR and GS) of the aircraft can be determined only by combining the motion of the air mass relative to the surface (W/V) and the motion of the aircraft relative to the air mass (HDG and TAS).
In other words:

TR and GS = HDG and TAS + Wind Velocity

18.2.1 WIND DIRECTION: DCS VS REAL LIFE

At the moment of writing, the new dynamic weather has been shown in the 2022+ list of features, but we do not have an ETA yet.

Currently, the weather is quite static, and wind is set via the mission editor as the direction the wind is flowing to, plus its speed.

Figure 496: Wind direction in DCS.

The wind direction in-game, reported in the Weather info part of the briefing, was listed in a similar fashion as the mission editor until a recent patch[128].

Figure 496 shows a simple example of the wind in DCS and how now both the Wind direction *to* and *from* are displayed.
The F-14A in located on a runway facing South. At the end of the runway I placed a fire effect (Insert Object → Effects). I set the wind as 090 at 10kts at ground level. As you can see, the wind is blowing towards the left of the South-facing F-14, which is 090.

> **Important!**
> For the purpose of this book, the Wind Direction is considered as the direction to, rather than rather than from; since this is how the wind was intended in DCS for more than a decade.

18.2.2 WIND COMPONENTS

The wind can be represented in a two-dimensional plane by a vector, hence with a *direction* and a *norm*. The direction represents the slope of the line, whilst the length is dictated by its norm.

128 Patch 2.7.5.10869, 11/08/2021.

Since the direction of the wind is calculated from the North, we can define as φ the angle between the wind vector and the North and *V* the norm of the vector. The projections of vector on the N-S axis and E-W axis are the two components of the Wind Velocity Vector: VY and VX (often indicated as *u* and *v*).

The value of the two components is obtainable by means of simple trigonometry:

$$V_X = V\cos(\phi)$$
$$V_Y = V\sin(\phi)$$

If, instead, we have the two components and we want to calculate the direction φ or the length *V*, we use Pythagoras and trigonometry:

$$V = \sqrt{V_X^2 + V_Y^2}$$

$$\phi = \arctan\left(\frac{V_Y}{V_X}\right)$$

Examples

By applying the formulas mentioned above, we can calculate each component of a given Wind vector:

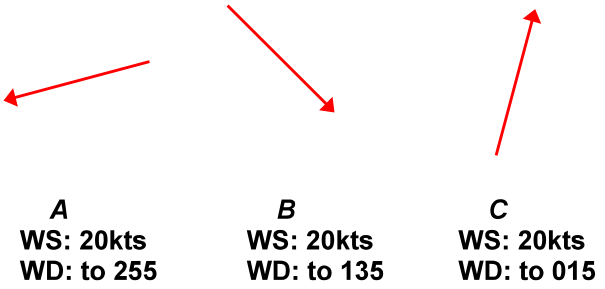

Figure 497: Wind components - Examples.

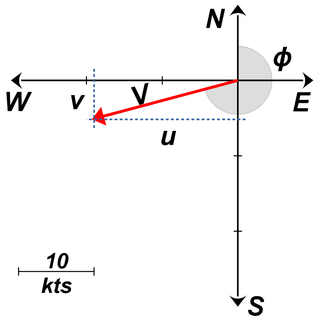

Figure 498: Wind components - Example A.

EXAMPLE A

WS: 20 kts

WD: to 255°

$$v = V\sin(\phi)$$
$$u = V\cos(\phi)$$

$$v = 20\sin(255°) = -19.31\,[kts]$$
$$u = 20\cos(255°) = -5.18\,[kts]$$

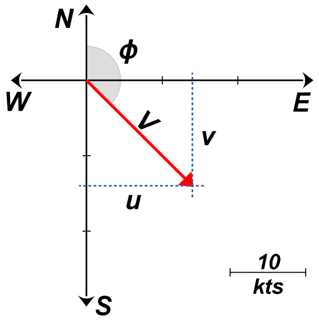

Figure 499: Wind components - Example B.

EXAMPLE B

WS: 20 kts

WD: to 135°

$$v = V\sin(\phi)$$
$$u = V\cos(\phi)$$

$$v = 20\sin(135°) = 14.14[kts]$$
$$u = 20\cos(135°) = -14.14[kts]$$

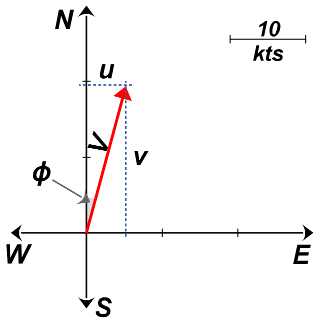

Figure 500: Wind components - Example C.

EXAMPLE C

WS: 20 kts

WD: to 015°

$$v = V\sin(\phi)$$
$$u = V\cos(\phi)$$

$$v = 20\sin(15°) = 5.17[kts]$$
$$u = 20\cos(15°) = 19.32[kts]$$

WIND COMPONENTS: FROM THE MATHS TO THE COCKPIT

VX and *VY*, the components of V/W, have precise definitions when applied to aviation:

- the **crosswind** component;
- the **headwind** or **tailwind** component.

The crosswind is defined as the wind blowing perpendicularly to the direction of travelling. In layman's terms is the component of wind that push the aircraft left or right, and it can be a serious hazard during take-offs and landings.
Tailwind and Headwind respectively blow following the direction of travel, or in the opposite direction. They impact the performance of the aircraft, and the length of take-offs and landing.

The magnitude of crosswind and headwind/tailwind depend on the direction the aircraft is operating.

18.3 EFFECTS OF ALTITUDE, TEMPERATURE AND PRESSURE

Temperature and Pressure are factors often ignored by desk pilots: we set the QNH according to the ATIS or the briefing, we then adjust it to 29.92 after a while, and we set it back for landing. End of the story.

However, there is an awful lot of things going on under the hood, as temperature and pressure affect directly the performance of an aircraft.

18.3.1 PERFORMANCE IMPACT

As the altitude at which the aircraft flies increases, the temperature drops and the pressure decreases.

High altitude is often considered being above 25,000ft, or flight level FL250. Flying higher brings a series of benefits and drawbacks, such as:

- the air surrounding the aircraft becomes colder as the altitude increases. The engines can burn more fuel without exceeding extreme temperatures.
- engines also operate more efficiently because cold air expands relatively more than warm air, allowing for more power to be generated using less fuel.
- the drag at high altitudes decreases, thus the aircraft flies faster given a set amount of thrust.
- the lower air density means implicates that to move the same amount of air through the engines, the aircraft needs to fly faster, and the control surfaces may reduce their aerodynamic efficiency.

18.3.2 INDICATED AIR SPEED AND ALTIMETER

The Indicated Air Speed is read through a pitot tube. Without going too much into the details, it uses the airflow to determine the IAS, then displayed to the pilot.

As we now, the cold air is denser than the warm air. Therefore, on a warm day, an aircraft has to fly faster to move the same amount of air it would do in a cold day. The density affects the amount of air displaced, which is reflected in the IAS reading.

In a similar way, an aircraft flying higher (less dense air), will show a lower IAS than an aircraft flying at the same TAS but at a lower altitude.

Altimeters function as barometers, and are calibrated using the International Standard Atmosphere (ISA).
In cold air, the altimeter over-reads, since air is denser, and the pressure at the various levels is lower than the ISA, whereas in warm days the opposite happen.

In terms of safety of flight, different temperatures and pressures are not a problem as every aircraft should be on the same page, all affected by the same effects. However, this can be a concern in terms of terrain avoidance, and the pilot should take this factor into consideration when operating in a mountainous area.

18.4 EARTH'S MAGNETIC FIELD, MAPS & NAVIGATION

The difference between True North and Magnetic, and the effects of the Magnetic Variation over avionics, navigation, INS update and so on, have been discussed multiple times in this book. This Chapter briefly covers some of the practical effects that the Magnetic Variation has when it comes to flying between two points.

18.4.1 MAPS: MAGNETIC VS TRUE

Navigational Maps are usually oriented towards the True North. Directions referred to this point are indicated with a "**T**" and are called "*true directions*".

True directions have the drawback of being hard to use for pilots, especially in order aircraft, as the usual primary tool for determining the direction aligns itself with the Magnetic North (as a compass does).

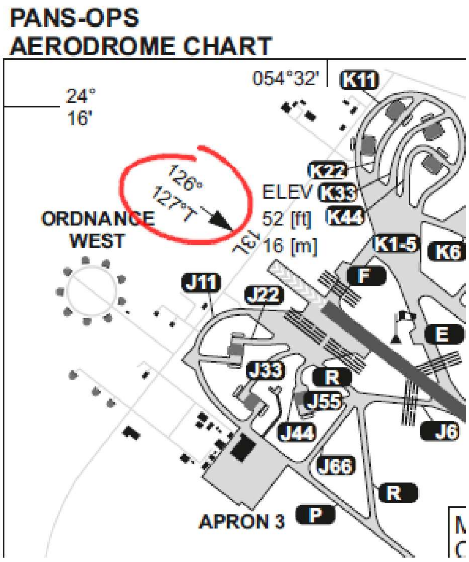

Figure 501: Al Dahfra FLIP - RWY 13L magnetic and true.

There are two magnetic poles on the planet, the "*North Magnetic pole*", and the "*Southern Magnetic Pole*". Plate 24 represents Earth's magnetic field[129].

A magnetized object, free to rotate and move, will align itself with the north-south lines of magnetic force. Directions referring to the magnetic pole are called "*Magnetic directions*", often indicated with an "**M**".

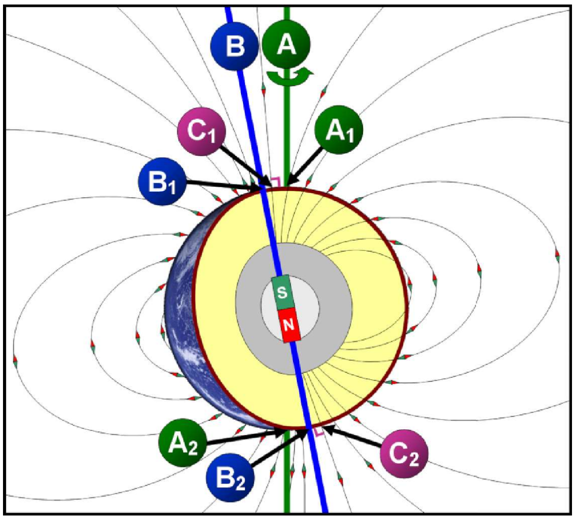

Plate 24: Earth's magnetic field - Source Wikipedia.

As discussed in previous Chapters, the difference (angle) between the True direction and the Magnetic direction is defined as the "*Magnetic Variation*".
This value must be taken into account when using standard Navigation Maps, and even when playing a simulation such as DCS.

18.4.2 ISOGONAL LINES

The Isogonal lines reported on maps such as the Navigational Chart in Plate 25 help the crew to determine the value of the Magnetic Declination.

129 Source Wikipedia – Relationship between Earth's poles. A1 and A2 are the geographic poles; B1 and B2 are the geomagnetic poles; C1 (south) and C2 (north) are the magnetic poles.

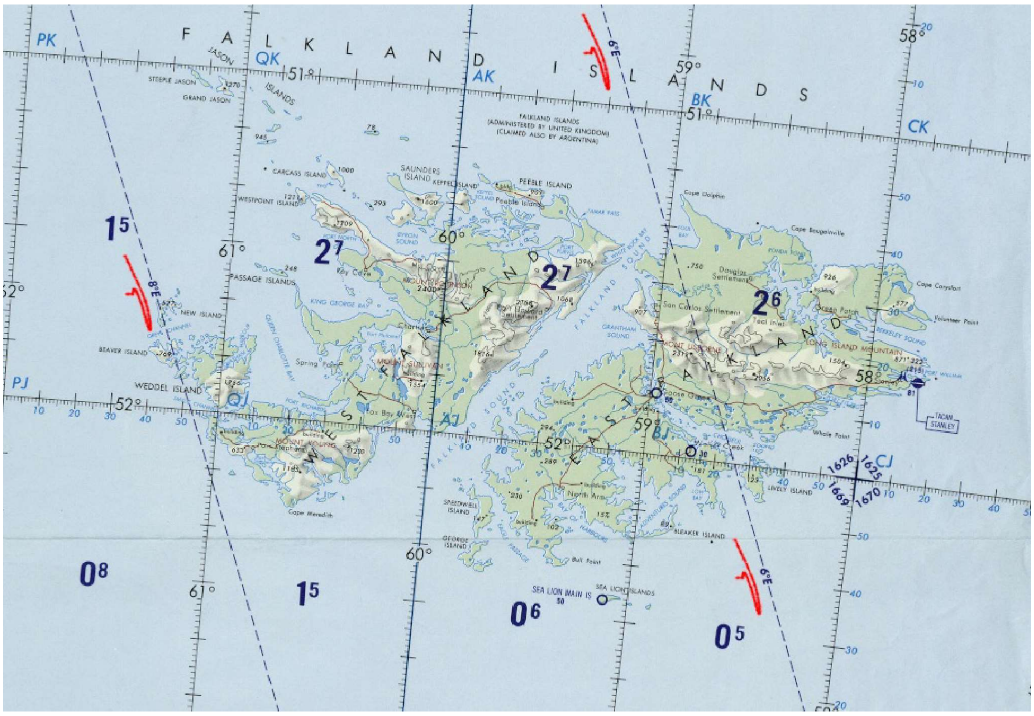

Plate 25: Isogonal lines on the Falklands Island map - maps.lib.utexas.edu.

The usage of these maps in for DCS has a few issues, for instance:

- the Earth's magnetic field changes depending on the year, so you need appropriate maps for the time-setting of your mission;
- the maps in DCS, albeit similar, are do not faithfully recreate all the geographical features of an area;
- another more practical issue is the size of the maps and the cost, unless you have a proper A3 printer or even bigger.

Navigational Charts and maps can be found via a simple query in any search engine.
The following are a couple of sources, from both the community and external agencies:

- https://www.digitalcombatsimulator.com/en/files/3311902/
- https://www.digitalcombatsimulator.com/en/files/3305623/
- University of Texas: https://maps.lib.utexas.edu/maps/onc/
- SkyVector, a tool to make flight plans online: https://skyvector.com/

18.4.3 THE DCS MAP: F10

Most DCS players are familiar with the F10 Map. Depending on the server or mission settings, it can show every object in the map, or nothing at all. Most casual servers show either everything, or at least the player's aircraft location and the friendlies.

The F10 Map suffers from the same issues of a real navigational map: it is oriented towards the True North. Therefore, when used for planning or navigation, the player must remember to take into account the Magnetic Variation, especially over long distances and if the MagVar is greater than a couple of degrees.

Remember that the Magnetic Variation changes depending on the year the mission is set. There are several sources of such value, both in-game (i.e. the Kneeboard of the F-14) or online. One of the first results on Google is the Historical Magnetic Declination map made by the NCEI (National Centers for Environmental Information).

18.5 NAVIGATIONAL AIDS & AVIONICS

The following is a recap of the common Navigational Aids and devices available to the crew.

Note that some of them may not be available to every aircraft. For example, the F-14 Tomcat's ability to function as a rudimentary Ground Radar is closer to a side effect of the Pulse radar function, rather than a fully fledged Ground radar.

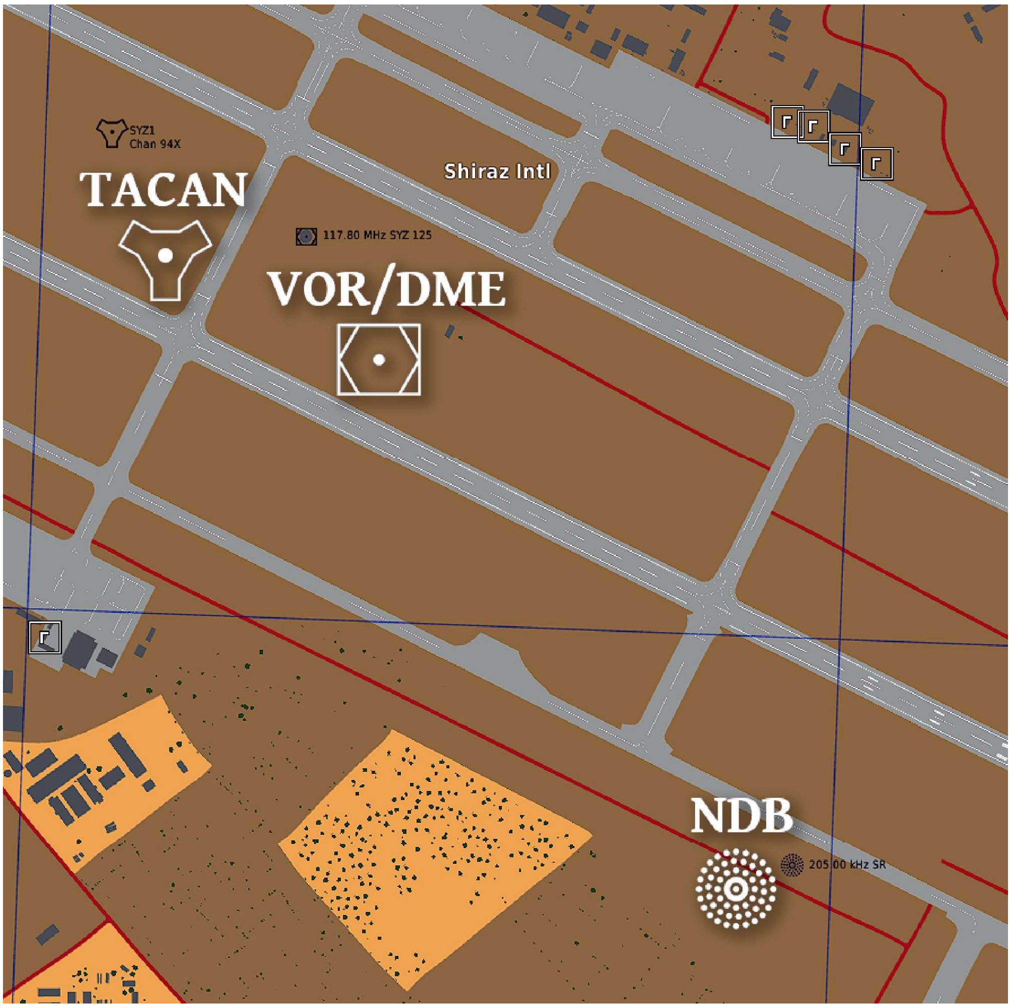

Figure 502: Nav aids - TACAN, VOR/DME, NDB.

Figure 502 shows some of the navigational aids available in DCS: TACAN, VOR/DME and NDB. The frequency or channel related is displayed next to the symbol.

Additional details about these Navigation Aids useful for playing DCS are discussed below. If you are interested in the topic, a much more in-depth and comprehensive list is available on the website of the US FAA (Federal Aviation Administration).

18.5.1 TACAN

The most commonly used navigational aid, the TACAN is routinely employed in most recoveries, whether on land or carrier, but also to maintain awareness about the range (and, in some cases, the bearing) of other friendly airborne assets.

See Chapter 6.1.2 for more information about this device.

Figure 503: TACAN

18.5.2 VOR

VOR stands for "*VHF Omnidirectional Range*". These stations use the VHF frequency range and provide the azimuth towards the VOR station, but no distance between the aircraft and the VOR.
The VOR radio signal requires lines of sight, and offer shorter range and detection altitude than, for example, NDB. The working principle is different too: the VOR sends two messages, the first equal in all directions, the second differently modulated depending on the direction. It is the phase difference between the two signals that reveals the magnetic course towards the station. This approach increases the precision of the azimuth.

Although the VOR do not provide the distance to the station, in DCS two VORs can be used to determine the aircraft by Triangulating the directions (see Chapter Error: Reference source not found).

The VOR is identified by a Morse code identification message.

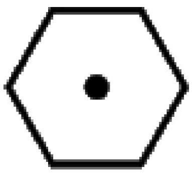

Figure 504: VOR.

VOR/DME

The VOR/DME are a particular type of VOR stations, able to provide bearing on top of distance, thanks to the combination of a VOR and a DME.
VOR/DME are not implemented in DCS at the moment, and the work as VOR stations do.

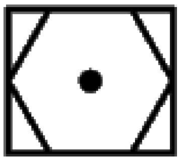

Figure 505: VOR/DME.

VORTAC

Another expansion of the original capabilities of the VOR is the VORTAC: the combination of a VOR system along a TACAN station. Both VOR and TACAN provide the azimuth but, usually, the TACAN is used by the military, whereas the VOR by the civilians.

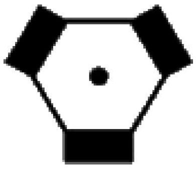

Figure 506: VORTAC.

18.5.3 NDB

Non-Directional Beacons are relatively old, and in many ways outdated, means of navigation.
NDBs sends an AM signal in all directions, and although they have some advantages over other means (for example, they offer a greater range, and in real life they are fairly cheap to install and maintain), they are quite imprecise. Contrary to the VOR, for example, where the direction is encapsulated in the message, the NDB requires ad hoc hardware installed aboard the aircraft, increasing the sources of imprecisions.
Moreover, the direction provided by the NDB station is related to the course of the aircraft, further increasing the chances of imprecisions.

Non-Directional Beacons are identified by a specific name (or callsign) transmitted via Morse code. The NBD shown in the bottom-left corner of Figure 502, for example, has callsign "SR". The radio signal will therefore sound like this:

> ... .-.

NDB IN DCS

The usage of Non-Directional Beacons in DCS is limited due to the frequency range they operate. The F-14, for example, is unable to use NDBs, but the Mi-8 and the L-39 can.
Using the example in Figure 502 again, the VOR/DME frequency 117.80 MHz operates in VHF range, but the NDB located at the Shiraz airport has frequency 205.00 kHz, therefore in the Extremely Low Frequency (ELF) range. [[double check, writing by heart]].

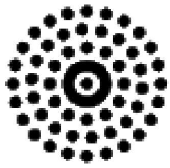

Figure 507: NDB.

18.5.4 ADF

The Automatic Direction Finder is the function that enables the usage of radio signals (such as the ones provided by Non-Directional Beacons), rather than a navigational aid itself.

The ADF is, in simple terms, a compass pointing (ergo showing the relative bearing) towards the direction of the selected frequency emitter (normally and NDB). In order to provide such value, the ADF typically uses two antennas, the combined output data used to drive the ADF needle displayed in the cockpit.

The following is an extract from an ICAO[130] document that provides more technical details about the ADF antennas and functioning principle.

The Loop Antenna

> *The loop antenna can be simplistically described as two insulated coils of wire wound perpendicular to each other onto a ferrite core. The bi-directional antenna is horizontally polarized, and couples with the magnetic component of the beacon signal. The maximum voltage is induced when the antenna coil is perpendicular to the transmitter. As the antenna pattern contains two nulls, it cannot determine whether the signal is from the 0° or 180° position, hence the need for the sense antenna.*
>
> **ICAO – DESCRIPTION OF NDB AND ADF OPERATION AND DEFINITION OF PROTECTION REQUIREMENTS. PAGE 3.**

The Sense Antenna

> *In its basic form, this can be a long wire antenna, often seen mounted from the aircraft cabin roof to the tail fin. For more modern types of antennae, both loop and sense are located in the same teardrop-shaped housing, mounted as near to the aircraft centreline as possible. This omnidirectional capacitive antenna couples with the electric component of the signal.*
>
> **ICAO – DESCRIPTION OF NDB AND ADF OPERATION AND DEFINITION OF PROTECTION REQUIREMENTS. PAGE 4.**

130 ICAO: International Civil Aviation Organization – Website.

The Composite Effect

> *In a typical ADF receiver, the signals received by the loop and sense antennae are combined to create the equivalent of a cardioid pattern, as shown in [Plate 26].*
> *As is often the case, the resultant signal null is more discrete than the maximum zone. Therefore, the ADF equipment can be positively and accurately tuned to the null. The ADF electronically and/or mechanically aligns the null with the transmitter station by rotating a goniometer. If the goniometer coil is not exactly in the null, a loop voltage will be generated which is applied to a bi-phase motor which rotates the goniometer until it is in the null. Since the phase of the loop antenna signal either leads or lags that of the sense antenna depending upon which side of the null the rotor is positioned, the goniometer can be rotated in the correct direction to achieve the null.*
>
> *The output from the goniometer is then used to drive the needle on the ADF display in the cockpit.*
>
> **ICAO – DESCRIPTION OF NDB AND ADF OPERATION AND DEFINITION OF PROTECTION REQUIREMENTS. PAGE 4.**

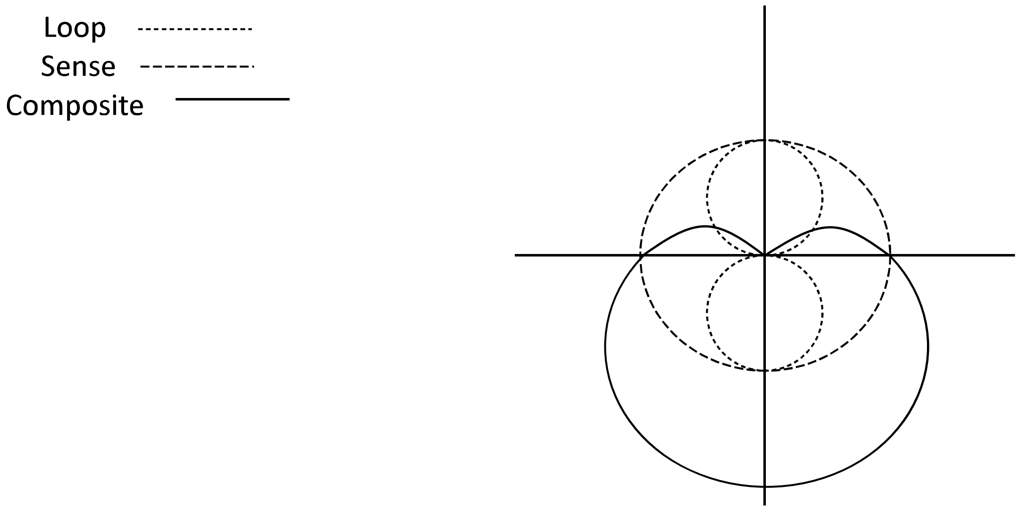

Plate 26: ADF Antenna Patterns - Source ICAO.

18.5.5 INS

The Inertial Navigation System has been profusely covered in this book already (see Chapter 2.7, and 6.11 and subsequent).
The precision of the INS increased drastically through the years, heavily impacting the job of the Navigator himself, which now had a reliable tool capable of tracking the position of the aircraft even where no visual reference landmarks were available.

Moreover, being it aboard the aircraft and does not require external references after the initialization process, it is immune to jamming and deception – a valuable feature in times of war.

18.5.6 GPS

The GPS, acronym for "Global Positioning System", is a common tool in any phone, ad hoc device such as the embedded car navs, handheld devices used by hiker and so on. The GPS single-handedly revolutionized the way we move or fly in any unknown area.

Most modern aircraft in DCS have an onboard GPS. The F-14 lacks one, and the only way to have one currently is by purchasing the NS 430, a GPS module, a replica of the homonymous Garmin product.

The GPS is controlled and maintained by the US Department of Defence. It is clear how this poses a security, logistical and organizational threat to any non US-ally. For that reason, alternative GPS systems are in use and are maintained by different countries.
Examples, with global coverage, are:

- *GLONASS*: Russian-based satellite navigation system, comparable to the US GPS system;
- *Galileo*: created and maintained by ESA (European Space Agency) and the European Union;
- *BeiDou*: China-based satellite nav system.

On top of these three examples, other regional alternatives exist[131].

In a military context, the GPS is an incredible tool, although it can be jammed and in some cases spoofed.

18.5.7 GROUND RADAR

> **Note**: this topic is potentially long and complex, so I stick to the DCS perspective.

Most radars in DCS are capable of returning an “image” of the ground, either discernible or not. This is usually a problem, as ground returns mask potential hostile targets. However, this feature means that most of them can be use as rudimentary mapping tools, whereas others, more flexible, can provide fully fledged images of the ground.

Fighters such as the F-14 can benefit from the ground returns of the Pulse Radar mode in certain situations, for example when "feet-wet" to spot a ship or the coastline, as demonstrated in Chapter 8.2.2.
The radar suite mounted on the F/A-18C Hornet instead, has a dedicated ground mapping feature, capable of surprisingly precise and detailed images of the terrain.

131 Souce: Satellite Navigation – Wikipedia.

The images below show the same scenario from the perspective of the F-14A Tomcat (AWG-9), and an F/A-18C Hornet (APG-73).

Figure 508: Ground Radar - Scenario.

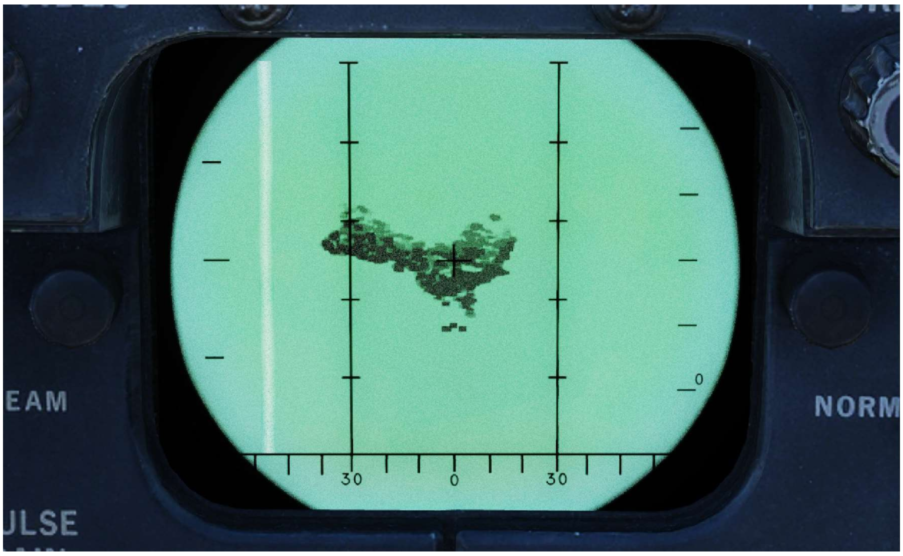

Figure 509: Mapping - AWG-9 Pulse Radar.

Figure 510: Mapping - APG-73 Ground Radar.

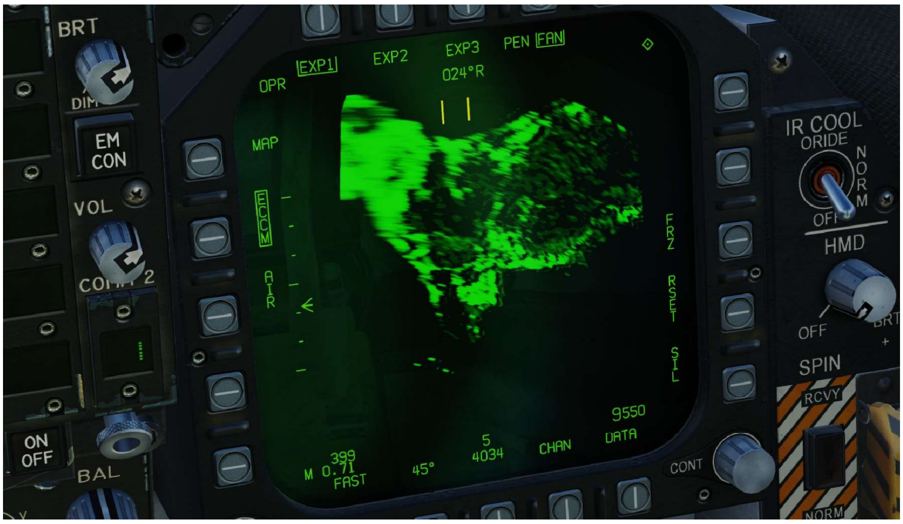

Figure 511: Mapping - APG-73 Ground Radar (EXP1).

Although even the most basic ground mapping radars can be useful in niche situations, radars with dedicated ground mapping features drastically raise the bar in terms of navigation, positional awareness and ground target spotting ability.

19. NAVIGATION II: PRE-GPS ERA

19.1 EVOLUTION OF THE "NAVS" – BRIEF HISTORY

The concept of the "Navigator" stretches back centuries, albeit under different names. The "Rise of Flight" and the advent of aircraft capable of flying from the initial few meters to tens or hundreds of kilometres, opened a vacancy in the crew: someone had to have the ability of understanding the position of the aircraft, and calculate the information necessary to reach the destination.

Some aircraft required more than one Navigator (such as the famous V-force), and in the 70s, the RAF syllabus for a navigator included topics such as celestial navigation, using devices such as the sextant to determine the position of the aircraft.

As often happens, technological progress revolutionised the role of the navigator.

19.1.1 FROM THE SEXTANT TO THE INS

The book "*Observers and Navigators: And Other Non-Pilot Aircrew in the RFC, RNAS and RAF*", by C. G. Jefford, covers in-depth the story and the evolution of the role of the Navs.

> *The 1960s was a decade of change, and when the newly qualified navigator was assigned to an operational role, he would more than likely find that his aeroplane was equipped with a Doppler radar which measured drift and groundspeed. Since heading and airspeed were already known, the availability of Doppler meant that the navigator could always calculate the direction and speed of the local wind. In other words, from the 1960s onwards, since the navigator (nearly) always knew the dimensions of all three sides of the triangle of velocities, he had a permanent solution to the*

problem which his predecessors had spent much of their time trying to solve.

[..] it was now possible to resolve the output of the Doppler radar around heading in a Ground Position Indicator (GPI) which provided a read out of the actual (strictly speaking, computed) position of the aircraft. As a result, the air plot technique, which had provided the basis of air navigation since before WW II, was replaced by the track plot.

[..]By the 1970s navigators undergoing basic training were being taught to handle Doppler radar and analogue computers.

OBSERVERS AND NAVIGATORS: AND OTHER NON-PILOT AIRCREW IN THE RFC, RNAS AND RAF. GRUB STREET PUBLISHING.

19.1.2 PARENTHESES: THE F-14 TOMCAT

The F-14 Tomcat has an Inertial Navigation System, the AN/ASN-92, along a TACAN system and the ADF, providing a good number of navigational tools to the RIO. The INS in particular, for the time, was a very good device, used on the A-6E TRAM as well.

Although, for the most part, the routine of the RIO involved mostly updating the fix if necessary, operative employment always required careful planning.
The "*TARPS*[132]" mission described by Dave "Bio" Baranek explains in his recent book, "*Tomcat RIO: A Topgun Instructor on the F-14 Tomcat and the Heroic Naval Aviators Who Flew It*", is a great example:

We had an INS, but we couldn't rely on it for this mission. When it worked perfectly, INS was like the GPS so familiar today, but on TARPS missions our primary navigation was visual. We used the charts we'd prepared and the visual navigation techniques we'd learned early in our training: look ahead between 10 o'clock and 2 o'clock and pick out landmarks, then come inside and find them on the chart. [..]

Settled into the mission, I assumed my responsibilities for navigation. "Our next waypoint is power lines crossing a road, coming up in twenty seconds. We continue heading zero-eight-nine. The next turn point will be at time 5 plus 32: six storage tanks. We are two seconds ahead of time. Fuel is above plan." [..]

132 TARPS - Tactical Airborne Reconnaissance Pod System. It is essentially a set of camera mounted in a pod, and carried by the F-14. The TARPS pod is not implemented in DCS yet, but Heatblur stated that they may look into a simple implementation. It would be a great addition to the F-14, and a whole new type of mission no other aircraft can do in DCS at the moment. More information – Wikipedia.
Another great source of information is Episode #10 of "*F-14 Tomcat*".

Then, in full compliance with Murphy's Law, something bad happened: ground fog.
In an instant we were flying in whiteout. Forget the eyeballing. We had planned carefully, so we knew we weren't going to hit anything, but we couldn't be certain we were on route and on time. [..]

"Where are we, Bio"?
"We're on the route, on time. Continue heading one-zero-six".

DAVE "BIO" BARANEK – TOMCAT RIO. PAGE 102/103.

You can find out how the mission ends in Bio's book (don't hate me, get the book! ☺).

The quote above greatly shows the importance of learning the basics of navigation – at least what is meaningful and helpful in a simulation such as DCS.

Note: Bio's book as a very interesting images showing the navigational notes for a TARPS mission dated 1989. If you have a physical copy of the book, you can find the image at page 102.

19.1.3 LATE 80S: FROM MANUAL FIX UPDATES TO THE GPS

"*Observers and Navigators*" continues the discussion of the evolution of the Nav role into the modern day.
Here comes another revolution: the *Global Positioning System*.

Since a late-model Doppler/inertial system provided both a precise heading reference and very accurate velocities, the only remaining scope for improvement lay in fixing. This loophole was finally closed by the introduction of the satellite-based Global Positioning System (GPS) which is capable of locating a receiver within a matter of yards.

[..] So long as it knows its position at the start of a mission, ie the precise geographic co-ordinates and the alignment of its dispersal or hardened aircraft shelter, the error accumulated during a sortie by a state of the art INS, which requires no external reference whatsoever, is measured in yards, not miles. Furthermore, the three-dimensional mapping databases which can be loaded into a modern navigational computer are now so accurate that they can be used both to navigate and to fly at low level on autopilot in the dark and/or in cloud by comparing radar altimeter returns

OBSERVERS AND NAVIGATORS: AND OTHER NON-PILOT AIRCREW IN THE RFC, RNAS AND RAF.
GRUB STREET PUBLISHING.

Although the GPS has its drawbacks, for example it can be locally jammed and can be spoofed, it is undoubtedly a great addition to any aircraft navigational toolset. Moreover, the GPS is not the only tool available for navigation, and the modern INS are incredibly more accurate than the AN/ASN-92 mounted in the F-14A.

Eventually, the evolution of the Navigator later resulted into the genesis of the WSO:

> *[..] by the late 1980s it was becoming difficult to foresee a situation in which a crew might have to revert to the relatively primitive manual techniques of yesteryear. In other words, the traditional 'navigator' was rapidly becoming redundant. The extent to which this was true varied, but the RAF was already operating aeroplanes (like the TriStar) entirely without navigators in roles in which they would have been considered essential only a few years earlier. Furthermore, because navigation was now hyper-accurate and largely computer-based, even where they were being retained, few navigators needed to devote much time to establishing their aeroplane's position.*
> *During an operational sortie, the back-seater in an early 21st Century attack aircraft will concentrate relatively briefly on the aiming and delivery of whatever weapons his aeroplane is carrying, spending most of his time monitoring and operating the array of warning and defensive systems carried by his aircraft.*
>
> **OBSERVERS AND NAVIGATORS: AND OTHER NON-PILOT AIRCREW IN THE RFC, RNAS AND RAF. GRUB STREET PUBLISHING.**

Across the pond, the evolution was different, but followed the technological advancements.

Although the figure of the GiB ("Guy in the back") changed across different platforms, the book "*A-6 Intruder Units of the Vietnam War*" provides an interesting and concise overview of its development.

> *The addition of the second seat was critical, as no small part of the Intruder's eventual success was in fact due to its crew of two – a Naval Aviator and a Bombardier-Navigator (B/N), the latter being a commissioned officer who was initially rated as a Naval Air Observer (NAO).*
> *The concept of the NAO went back to observers in World War 1-era aircraft, and it had developed over time to include navigators and gunners, many of which were enlisted men or warrant officers, particularly in the Marine Corps.*
> *The advent of jet aircraft and complex 'weapons systems' led to training commissioned officers as B/Ns, initially in the heavy attack community. Within the carrier US Navy in the early 1960s the introduction of the F-4, A-5, A-6 and E-2 all led to a rapid increase in the population of NAOs.*
> *The NAO designation became Naval Flight Officer (NFO) on 1 May 1965. Five years later NFOs became eligible for command, something that had been reserved for pilots in aviation units up to then.*

> *[..] In this regard the US Navy, much to its credit, established precedence well ahead of its USAF brethren, as it recognised that talent did not depend on who held the controls.*
>
> **A-6 INTRUDER UNITS OF THE VIETNAM WAR: 93 (COMBAT AIRCRAFT).**

19.1.4 THE GAMING SIDE: PERSONAL EXPERIENCE

In video-games such as DCS, navigation is often simplified by the availability of modern avionics, Controllers (although primitive), and other tools, some of which are less-realistic, such as the "Kneeboard GPS" or the "*F10*" map.

However, other games simulate different types of aircraft in a different time settings. For example, in the early 2000s, the teenager myself played *IL2 Sturmovik* and its expansions almost every evening. Although I played Falcon 4.0 a bit before setting the clock back 50 years, the navigational skills I acquired in the Viper were incredibly scarce.
IL2, on the other hand, forced me to learn to navigate in an "empty" cockpit. The solution I found was simple: print the maps of the game, grab a goniometer, pen and paper, and use a combination of Checkpoints plus visual references to determine my position. Back then, I did not use any stopwatch, and I had no idea of the effects of temperature, pressure, and altitude. All was good… as long as the weather held.

Unbeknown to me, a somewhat similar approach, but immensely more refined, was used in real life as well.

Fast forward to the 2008, then Black Shark was released. The ABRIS is an amazing tool: it has a moving map, and shows all sort of information and details, useful for navigation and planning. Why bothering to learn how "it was done"?
Well, the F-14, the upcoming F-4 and the A-6 are a good reason: the missions and their planning described in books about the Iranians F-5 and F-4, the Israeli "*Kurnass*[133]", not to mention the TARPS mission such as the one mentioned above by "Bio", are as fascinating as neglected in DCS.

Thinking about it, it is incredible how little attention is generally given to the navigation-side of a mission. Luckily, there are exceptions.

19.2 THE WIND TRIANGLE

The effects of the wind mentioned in the Chapter XXX can drastically affect the journey of an aircraft. Besides the effects in the critical phases of departure and landing, the wind-

133 "Sledgehammer", the name the Israeli gave to the F-4.

induced drift can push the aircraft away from its intended course. This impact the fuel reserves and can prevent an aircraft from finding its target.

The drift can be measured as the angle between the intended heading and the actual course of the aircraft. The protrusion of the heading and course lines can be closed with a vector representing the wind, resulting in a triangle.

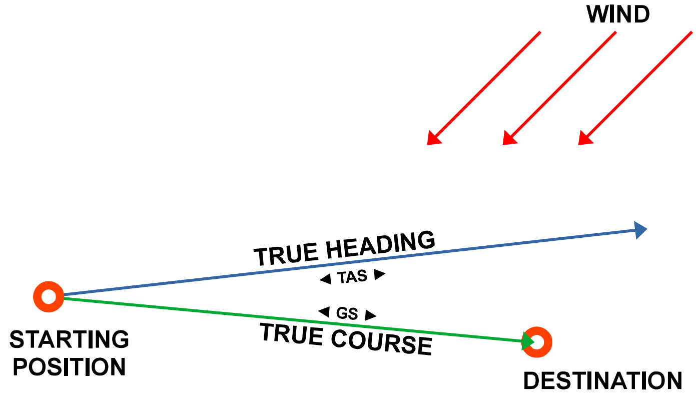

Figure 512: Wind Triangle - Scenario.

The triangle is called "*Wind Triangle*". Each side is represented by a vector; thus they have a length (norm) and a direction. This allows to use both the basic notion of the Euclidean vectors and trigonometry to calculate the effects of wind. Specifically, the parameter necessary to compensate for the wind is the angle originated by the Course and the Heading and called **Wind Correction Angle** (WCA).
The WCA is, is simple terms, how much the aircraft has to turn into the wind to compensate for the drift it induces. Once this value is know, it can be used to adjust the aircraft heading and maintain the planned course (ergo the course matches the track).

19.2.1 WIND CORRECTION ANGLE VS DRIFT ANGLE

As discussed, the Wind Correction Angle is the angle the aircraft should compensate for to maintain its track over the planned course.

The Drift Angle is the angle that describes how off the track is compared to the planned course.

Although similar concepts, the Drift Angle changes according to the track. In theory, if the track angle is zero, DA and WCA are equal value, but opposite in sign. However, if the track is not zero, then Drift Angle and Wind Correction Angle are different.

For the purposes of this simple discussion, Drift Angle and Wind Correction Angle are considered equal.

19.3 DETERMINING THE WIND CORRECTION ANGLE

The following example shows how the Wind Correction Angle can easily calculated using simple trigonometry.

> **Note**: The values used in the example have been selected to make the angles more apparent and the example simpler, rather than realistic.

TAS = Aircraft True Air Speed;
TC = Aircraft True Course;
WS = Wind Speed;
WD = Wind Direction.

Red line = Wind vector;
Blue line = True Heading vector, norm = TAS;
Green line = True Course vector, norm = GS.

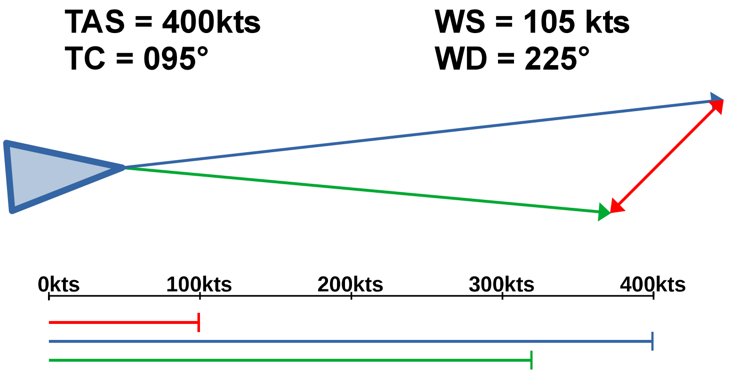

Figure 513: Determining the Wind Correction Angle.

The mathematical approach is probably more interesting and useful to a virtual backseater, as it can be easily applied to a spreadsheet, simple mobile app or, in my case a second 2.8” TFT data-fed via DCS-BIOS a new feature for my Mission Datacard Generator.

Let’s start by assigning names to sides and angles:

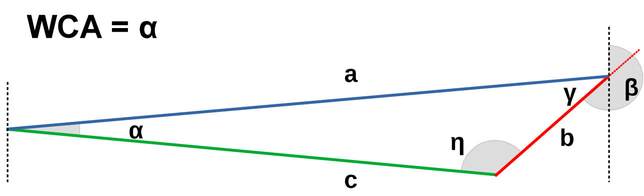

Figure 514: Angles of the Wind Triangle.

WIND CORRECTION ANGLE

The angle η is immediate:

$$\eta=\delta-\beta=95°-225°=-130°$$

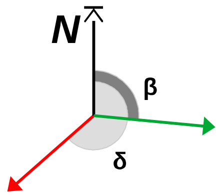

Figure 515: Determining η.

Now, using the Law of Sines, we can calculate α, or the WCA:

$$b=\frac{\sin(\alpha)}{\sin(\eta)}\cdot a$$

From which we obtain the WCA:

$$\alpha=\arcsin\left(\frac{b\sin(\eta)}{a}\right)=\arcsin\left(\frac{105\cdot\sin(-130)}{400}\right)=-11.6°$$

The sign indicates that the correction is towards the left. In fact, as clearly visible in Figure 513, the wind is coming from the same direction.

For the sake of completeness, we can calculate the Wind Correction Angle for a scenario with the same parameters, but different wind direction.
Considering *WD* = 315°, and the same parameters for the aircraft, for example:

$$\eta=\delta-\beta=95°-315°=-220°$$

$$\alpha=\arcsin\left(\frac{b\sin(\eta)}{a}\right)=\arcsin\left(\frac{105\cdot\sin(-220)}{400}\right)=9.71°$$

In this case, the wind comes from the right, and the WCA is positive.

As a final example, we maintain the speed of the wind and the aircraft, but set TC = 190° and WD = 120°:

$$\eta=\delta-\beta=190°-120°=70°$$

$$\alpha=\arcsin\left(\frac{b\sin(\eta)}{a}\right)=\arcsin\left(\frac{105\cdot\sin(70)}{400}\right)=14.28°$$

This last example sees the aircraft flying South, with wind pushing towards the South-East (towards the left from the aircraft's point of view). The correction is therefore towards the right.

TRUE HEADING

Once the WCA is obtained, we can proceed and calculate the True Heading the aircraft should follow to reach its destination. Keep in mind that this is the true value, the Magnetic Variation has not been considered into the equation yet.
The True Heading is the True Course taking into account the effect of the wind, represented by the Wind Correction Angle:

$$TH = TC + WCA$$

GROUND SPEED

The last step is the determination of the Ground Speed. It can be calculated via different means, for instance Law of Cosines.

Using the same nomenclature expressed in Figure 514, we find:

$$c^2 = a^2 + b^2 - 2ab \cdot \cos(\gamma)$$

$$c = \sqrt{a^2 + b^2 - 2ab \cdot \cos(\gamma)}$$

γ is not know, but it is immediately obtainable:

$$\gamma = 180 - \eta - \alpha$$

Applying the new formula to the original example, we find:

$$\gamma = 180 - \eta - \alpha = 180 + 220 - 9.71 = 390.29°$$

$$c = \sqrt{a^2 + b^2 - 2ab \cdot \cos(\gamma)} = \sqrt{400^2 + 105^2 - 2 \cdot 400 \cdot 105 \cdot \cos(390.29)} = 313.83$$

The resulting Ground Speed is 313.8 kts.

> **Note**: if 390.29° looks confusing, applying the modulo operator should help, resulting in 30.29°.

PECULIARITY: WIND DIRECTION = TRUE COURSE

A simple case to test the formulas discussed is the wind having the same direction of the aircraft or its reciprocal.

SAME DIRECTION		DIRECTION = RECIPROCAL	
TC = 95°	WD = 95°	TC = 95°	WD = 275°
TAS = 400 kts	WS = 105 kts	TAS = 400 kts	WS = 105 kts
$\eta = \delta - \beta = 95° - 95° = 0°$		$\eta = \delta - \beta = 95° - 275° = -180°$	

Let's consider the WCA formula:

$$\alpha = \arcsin\left(\frac{b \sin(\eta)}{a}\right)$$

In both cases, the Wind Correction Angle is zero because the *sin* of 0° and ±180° is zero, hence the argument of the *arcsin* is always zero, resulting in **α = WCA = 0°**. Therefore, the True Heading is changed in both cases.
This result is expect: the wind is not "pushing" the aircraft sideways, so no lateral correction is needed.
Next step is calculating the Ground Speed, starting from *γ*.

$\gamma=180-\eta-\alpha=180-0-0=180$
$\cos(\gamma)=\cos(180)=-1$

$\gamma=180-\eta-\alpha=180-180-0=0$
$\cos(\gamma)=\cos(0)=1$

The values of cos () already hints the final result. When applied to the Law of Cosine formula discussed above, we have:

$$c=\sqrt{a^2+b^2-2ab\cdot\cos(\gamma)}$$

For simplicity's sake:

$$a^2+b^2=171025$$
$$2ab=84000$$

$$c=\sqrt{171025+84000}$$

Resulting in Ground Speed = **505 kts**, which matches *TAS + WS*.

$$c=\sqrt{171025-84000}$$

Resulting in Ground Speed = **295 kts**, which **matches** *TAS – WS***.**

19.3.1 WIND TRIANGLE: OBSERVATIONS

The mathematical and geometrical relations between the two vectors allow a few immediate observations:

- the lower the aircraft's speed, the more the effect of the wind is pronounced.
  For example, considering a True course of 120°, Wind direction 60° at 20 kts, if the TAS of the aircraft is 200 kts, the WCA is 4.97°. If the TAS doubles to 400 kts, the WCA halves to 2.48°.
- the components of the wind impact the flight in different ways:
  - the highest lateral drift occurs when as the crosswind increases (the vectors tend to be perpendicular);
  - the highest change in ground speed occurs when the headwind or tailwind are stronger (the vectors tend to be parallel).

19.4 PILOTAGE AND DEAD RECKONING

Pilotage and Dead Reckoning are two navigation techniques that allow the crew to fly and point the aircraft in the planned direction.
Albeit different, the two methods show similarities and work best when they complement each other.

19.4.1 PILOTAGE

This method of navigating uses easily identifiable points (landmarks) to determine the position of the aircraft.
The first glaring problem with this technique is its reliance on landmarks or other visual points. In non-VFR conditions, when clouds, thick fog, heavy precipitations and other adverse weather phenomenon cause low visibility, finding the landmarks can be difficult, if not entirely impossible.
Another difficulty, depending on the area where the flight is taking place, is the lack of landmarks. In populated areas or peculiar uneven terrain, using a chimney, a large factory, or particularly high hill is possible. In the middle of a flat desert, it may not be so simple.
DCS does not help in this regard, as the next paragraph shows.

> *We also learned the art of visual navigation. Initially, this was done by standing between the two pilots to obtain a visual position line from a coastal landmark such as Land's End or Flamborough Head. However, in the latter stages of the course, we planned our route on a 250,000 scale topographic chart and 'route-crawled' from pinpoint to pinpoint whilst lying in the bomb-aimer's position on the lower deck. Of course, just as celestial navigation required the aircraft to be above cloud, visual navigation could only be undertaken when in visual contact with the ground!*
>
> **HERRIOT, DAVID. ADVENTURES OF A COLD WAR FAST-JET NAVIGATOR: THE BUCCANEER YEARS (P. 21).**

PILOTAGE: DCS VS REALITY

The differences between navigation and real life and DCS were briefly introduced in Chapter 18.4.2.
DCS maps vary in detail, and older maps tend to lag behind in terms of detail, precision and accurate recreation of real life. Even the excellent Syria map, made by Ugra Media, does not provide enough details to fully take advantage of a real map for planning and navigation.

Example: DCS Syria vs the real Golan Heights

The following photos were taken by 132nd.AssafB in the Golan Heights.
More photos, information and details about the area and its representation in DCS are available on FlyAndWire, along the high-res versions of Figure 516, 517 and 518.

Figure 516: Golan Heights - Part of the Hula valley (Left). The peak in the middle should be Mount Dov.

Figure 517: Golan Heights - Looking NE towards the Hermon.

Figure 518: Golan Heights - View from mount Varda, looking North towards the Hermon.

It is immediately visible how the map in DCS lacks many details, even taking into consideration the possible different year represented.

This makes planning using with real maps a challenging task, as the landmarks represented on the map, may not be present in DCS.

19.4.2 DEAD RECKONING

Starting from a known position, Dead Reckoning consists in flying by following a determined track, calculated factoring external parameters such as the wind and the magnetic variation.

The drawbacks of Dead Reckoning and Pilotage are different. Dear Reckoning can be used in adverse weather and low visibility, since it does not necessarily need a visual confirmation of the position of the aircraft. This puts a lot of emphasis on the piloting skill and the aircraft: the precision of the instruments can be a factor, and flying for several minutes at a constant speed is not as easy as it sounds.
Moreover, the weather can change in the timespan between planning and flight. Wind speed and direction being two important factors.

> *[..] our training focussed on learning the art of the Manual Air Plot (MAP)! This very basic method of air navigation required a continuous plot to be made of the true headings steered and the air distances flown, and the identification of the resultant track errors based on the discovery of the actual wind. Having prepared one's chart with the tracks to be flown between each turning point, a MAP required the navigator to adopt a rigorous and regular fixing cycle, and by advancing a previous position to a new one on the basis of assumed distance and direction moved, known as Dead Reckoning, a prediction of where the aircraft will be at a given time in space could be deduced. If successful, a heading correction was made in order to regain track effectively and efficiently; the method is known as 'DR'ing Ahead' and was usually based on a six-minute cycle. For it to be effective, it was essential that the pilot flew the aircraft at a constant Indicated Air Speed (IAS) which, in the case of the Varsity, was 180 knots or 3 nm per minute.*
>
> **HERRIOT, DAVID. ADVENTURES OF A COLD WAR FAST-JET NAVIGATOR: THE BUCCANEER YEARS (P. 20).**

DEAD RECKONING IN DCS

DCS offers a sense of safety to the crew: failures are non-existent, and the intrinsic imprecision of the avionics is not replicated (albeit Heatblur products include a realistic deterioration of the quality and precision of signal over distance, affecting for example the TACAN).

Currently, the weather is static, and visibility, wind speed and direction are predictable.

On the other hand, flying in a desktop simulator prevents the pilot from "feeling" the aircraft, making understanding when the aircraft is accelerating or decelerating almost impossible without looking at the instrumentation.

19.4.3 TRACK ERROR CORRECTION

When the crew realizes they drifted out of the planned track, they have to take action and correct. The "scholastic" procedure to correct the track error is the "One in Sixty" rule. However, this is classic PPL procedure that probably won't fit a jet flying at 400+ kts.

The following observations are from *Hawkeye*, Airline Pilot and Flight Instructor.

> *For the case of arriving at your visual checkpoint and you find that the aircraft's position is off from where you expected:*
> *1. Correct the aircraft position; Fly the aircraft where to it should be (as close to the checkpoint as possible)*
> *2. The course to fly to the next checkpoint should be in the navlog already with predicted WCA and magvar taken into account. If we don't have time for the following quick mental math prior to the turn, get the turn done, then do the adjustment while on the new course.*
> *3. Assuming the pilot flew the original course dead on and the aircraft still wound up out of position, we need to figure out if it was an incorrect WCA or error with the magvar (more often than not I'd bet it's going to be wind)*
> *4. Provided we decide the position error was due to wind: Using the WCA on the navlog, the predicted winds aloft, and the actual wind reading from the HSD, create a new WCA for the course and have the pilot apply the correction. Depending on how far off the aircraft was at the last checkpoint, the correction may only need to be a few degrees.*
> *5. If it's a magvar error... I imagine you have a decent solution to suss the correct magvar and fix it, but the same logic applies from point 4 once you get the correction figured out. In the real world, the magvar is plotted on our sectional charts so it's never really an issue midflight since the math is already done on the navlog.*
>
> *Realistically, a correction of a few degrees is going to be within the margin of error for a vast majority of pilots' skill level. At the airline transport certification level in the US, even we get +/- 5 degrees of desired heading when hand flying. Thus having visual checkpoints closer to each other reduces the opportunity for errors while navigating the course.*
> *For piston aircraft, typically 10-20NM is appropriate for visual checkpoints.*
>
> **HAWKEYE**

In the end, the conclusion about how to compensate a track error in a fast jet is rather simple: fly to the next fix (calculating true course from a map, and applying MagVar and WCA), and resume the flight plan from there.

19.5 AUTOMATIC DIRECTION FINDER (ADF)

> **Note**: The DF function in the real Grumman F-14 Tomcat is available for both the radio located in the front seat and the one located in the read seat. In DCS, only the radio actioned by the Radar Intercept Officer provides ADF functions.

The Automatic Direction Finder allows to navigate using a non-directional beacon (NDB) or similar radio navigation systems[134]. The ADF, in simple terms, "senses" the bearing where the signal is stronger, and determines the location (direction-wise) of the transmitter. Depending on the aircraft avionics and the station, the distance can be provided as well (DME).

Once the frequency of the NDB of choice is set, the aircraft can usually correlate by means of the Morse code transmitted by the station.

Practical Test

For this test I used a VORTAC[135] located in the Nevada Map. The first test shows the Direction Finder tuned to the station, along the TACAN, resulting in every needle pointing towards the nav-aid.

134 Non-Directional Beacons transmit a code via radio that, as the name suggests, do not include explicit directional information (those info are extrapolated by the avionics / other devices). VOR provide similar information but has shorter range. More information – Chapter 18.5.

135 A VORTAC consist in co-located VOR and TACAN stations. Tuning to the VOR provides bearing, tuning to the TACAN provides both range and bearing to the beacon.

Figure 519: ADF test - DF and TACAN tuned.

As the F-14 flies, the needles on the BDHI move towards 1 o'clock, then 2 o'clock and so on.

Figure 520: ADF test - F-14 flying past the station.

The perspective from the cockpit can be deceiving: Figure 521 shows the situation depicted in Figure 520 from the F10 map.

The F-10 view is also a good means to get information about the available nav-aid stations in the map, such as NDB, VOR, VORTAC, TACAN stations and so on. However, not every aircraft can use each of them at (Soviet / Russian aircraft tend to use NDB, NATO aircraft tend to use VOR/TACAN stations).

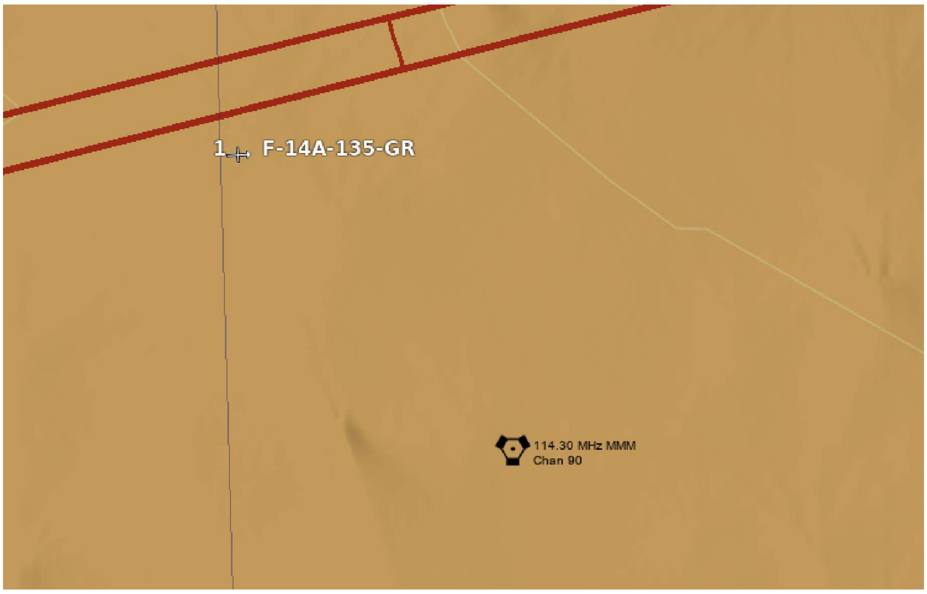

Figure 521: ADF test - Perspective from the F-10 view.


Figure 522: ADF test - Only DF tuned to VORTAC station.

Tuning to the station without using the TACAN, results in only one needle pointing towards the VORTAC station, and no distance is provided (Figure 522).

20. POST-MORTEM

In case you never had one or it is the first time you run into this term, a *post-mortem* in non-anatomy-related contexts is a discussion (or a meeting) usually held at the end of a project, or other occasions.

20.1 INTERCEPT GEOMETRY

Or *"Intercept Geometry: is it worth it?"*

The discussion about the Intercept Geometry was long and went too deep to be applied to DCS out of the box (or in a real situation, for the matter). The topics are, in fact, "school" notions, as Victory205 (SME for Heatblur) defined them. However, they provide a set of bedrock concepts that have concrete and immediate benefits.

Learning the "school stuff", gives unprecedented understanding of the scenario, boosting the ability of generating situational awareness faster and better, and therefore facilitates planning ahead and reacting to changes, ultimately leading to a tangible advantage in a virtual battle.

20.1.1 A CONCRETE EXAMPLE

Tactical Pascale recently (at the moment of writing) release a video about a simple GCI-driven intercept. In case you have not seen it yet, this is the YouTube link.

It is very well-made, simple to understand and provides a beautiful first look at a simple intercept.

So, why not take the occasion to a have a chat about what the "school stuff" allows you to understand versus the perspective of a player new to this topic?

THE NEW-PILOT'S POINT OF VIEW

Let's say a pilot unfamiliar with this topic watches the video and take notes. An imaginary bullet list would look like this (TP = Tactical Pascale), perhaps:

1. TP assessed the bearing, if it does not change, there is collision heading;
2. TP realizes the bearing is not changing;
3. TP plans the manoeuvre to create space;
4. TP, once the bearing has changed enough, turned towards the target again, creating a triangle, with the angles adjacent the hypotenuse quite similar (20°);
5. TP turns to the reciprocal;
6. TP, at a certain angle, starts the turn into the bandit.

It is a lot to digest for a new player, but there are valuable information here: for instance, the importance of a controller (especially a good one, and the AWACS in DCS is not one of them), on top of the ability of viewing the scenario from a different perspective, and to plan ahead using the information the pilot has.

Moreover, the video clearly shows how the mechanic of the intercept is quite simple when the target is cooperative:

- understand the situation;
- create space;
- use the created space to manoeuvre and gain a concrete advantage (FOX-2 from the RQ).

THE "SCHOOL STUFF" POINT OF VIEW

After studying the "school stuff", we have a much, much better understanding of what Tactical Pascale is doing.

In primis, we understand the ultimate objective: a stern conversion turn into the bandit's rear quarter, enabling both Visual Identification (VID) and FOX-2 employment versus a cooperative target.

We can immediately imagine the gameplan: we need a certain amount of Lateral Separation to make the turn, so we need to gain it (Cut-Away), lose it (Cut Into) or maintain it (Zero Cut). However, we do not have information about the Target Aspect, but this is easily solved by using the drift (which, at range, can take a bit of time – this is another limitation of the dreadful DCS AWACS).

Once we have the TA, the range comes from the BRA call, so we can determine the LS. At that point, we can implement the original gameplan, obtain a satisfactory amount of LS, then turn to Zero-Cut to lock it. Then, either the Counterturn tables (or other means), we can execute the conversion.

Now let's break down the process and have a look at the modus operandi.

“TP assessed the bearing”

What TP is describing, is the Drift, a recurring phenomenon that is really helpful to assess the situation. As we know, when there is no Drift, there is Collision Course. This notion is very useful for the RIO (or the pilot, in this case), as they can assess the bearing (or the Antenna Train Angle – ATA, as long as the Fighter Heading does not change) to immediately tell whether Collision is established or not.

“TP realizes the bearing is not changing”

It looks like that the bandit is coming straight towards to the fighter (ergo, Target Aspect is approximately zero). This means that there is no lateral separation, and if he wants to make a stern conversion later (at the moment the bandit is still at 70 nm), he needs to introduce some.

The problem in this scenario is that he will never build Lateral Separation, as flying towards the Bandit Reciprocal captures the Lateral Separation. In fact, the relation between the Target Aspect and the Range will be always constant.

“TP plans the manoeuvre to create space”

The explanation he gives is simple and on point: by turning away from the target, the lateral separation increases. This enables the Counterturn later on.

He does it by adding a ±50° offset (Cut Away). However, when deciding the angles, you should consider if the amount of offset is enough (or too much!). This is a good question: Tactical Pascale aims for an LS of 7-8 nm before the conversion, so approximately between 40,000ft – 50,000ft, and at the moment the target aspect is zero. It takes time to build it up. Just to be on the safe side, Tactical Pascale hit the burners, so the TA builds up quicker.

Note that the Collision captures the TA; therefore the ATA can be increased considerably and, when the goal is met, the fighter can simply turn to Collision. This usually works better than being very conservative with the offset, perhaps ending up with not enough LS, and requiring a Displacement Turn to regain it in extremis.

Back to the video, TP’s objective is to introduce a bearing of 330. Since he knows the BR and the bearing, he can immediately calculate the Target Aspect: TA = BR → BB = 310 – 330 = 20 Right.

“TP turns to collision”

Collision has the peculiarity of “locking” the Target Aspect: this is the ideal technique to apply when the objective (→building TA) is achieved. Another implication, is that the ATA does not change (and since the fighter’s heading does not change either, the BB is still the same).

In the video, Tactical Pascale builds an isosceles triangle with the angles at the base of 20° each. Those angles are the Target Aspect and the Antenna Train Angle, and this scenario occurs very frequently in the basic documentation. However, be careful with the speed: the

"CC → TA=ATA, but opposite is sign" relation works only when the aircraft are co-speed. The relations still kind of holds if delta speed is low enough, but the greater it is (imagine an F-14A gating whilst intercepting a Tu-95), the wider the difference between the two angles (Refer to this study to have an idea of the magnitude of the possible error if the heading of the fighter is not constantly corrected).

Back to the scenario, if the angles are maintained, the F-5 will physically impact the target. This is not the goal of the Stern Conversion intercept so, at some point, something has to change.

The formula TP used is one of the basic CCC (Collision Course Correction) formulas discussed in the CNATRA P-825/02 and on the website in the Intercept Geometry Study Part 7 (and the book as well): BR → BB → CC.

"TP turns to the reciprocal"

Flying towards the reciprocal of a target (Zero Cut) has multiple interesting implications:

- in primis the LS is locked: the range decreases, but the TA increases, and they balance themselves out;
- then, the ratio at which the angles change is knows: the TA doubles as the range is halved, and since TA=ATA in this case, the ATA doubles too. This allows us to predict what is going to happen in the future, and at what range (or angle) we should start the Counterturn (CT).

In the video, TP turns to reciprocal at about 25 nm. Assuming the TA calculated before is still more or less correct, the resulting Lateral Separation is: LS = 25 * 20 * 100 = 50,000ft. Spot on!

"TP, at a certain angle, starts the turn into the bandit"

This part is the simplest, as the fighter can be flown through a set of known gates until the matching parameters (again, those are known values) for the CT are met, and the turn.

The turn is easy at first, then harder as the TA increases. This manoeuvre positions the fighter in an excellent spot for a FOX-2 shot from the RQ or, like in this case, allows to level off and flying wing-level with the target.

Unfortunately, TP burned a bit of separation when his heading was slightly too hot, but eventually the manoeuvre was again spot on.

> *Fun fact*: this happened regularly to most of my pilots, without them realizing: some were distracted by the TID repeater, others were trying to Tally the target. You can tell that TP knows "a wee bit more" than us, desk pilots!

20.1.2 CONCLUSIONS

If it is not apparent yet, there's a metric ton of stuff going on behind the curtains, even in an intercept as simple as the one showed by Tactical Pascale. To such an extent that we can tell already that spending some time studying the basics of the intercept geometry really provides a more in-depth perspective. Most importantly, it allows the crew to quickly recognize and react to changes in the gameplan (e.g. if the target is jinking), and to understand the consequences that those changes have on the intercept.

So, to answer the question, is it worth it? Well, you tell me. The mechanical application of procedures such as the one described in Tactical Pascale's excellent video do not require any background knowledge, so it is entirely up to the player whether diving into the books or not.

Personally, my answer is a sound "**yes, definitely!**".

The only "regret"? You can get used to the sources and their availability, but unfortunately, the declassified documentation only goes up to a certain point. After that, it's a wall of "*it's classified*" or "*I can't talk about it*".

21. APPENDIX I: ADDENDA

This part of the book contains additional information, tests, articles from FlyAndWire and other content that does not fall into a specific topic.

For example, the Non-Co Speed Intercepts (Chapter 21.2) is a study not designed for operative purposes, but to understand the impact of the speed on the intercept. The documents studies so far, in fact, are all restricted to the co-speed, co-altitude scenario.

The overview of the Garmin NS 430 in DCS (Chapter 21.3) was inspired by the operational use of the Garmin Pilot III GPS during the last phase of life of the F-14. The module is not worth purchasing just for the F-14, but if you have it and you are flying in a setting post 90s, why not?

Other Chapters discuss wider topics, such as the IFF usage, a brief introduction, dedicated to pilots, about the most basic RIO operations.

21.1 RIO TRAINING IN SINGLE PLAYER

Training in a multi-crew module in single player is, no matter what you do, not as good as practising with two humans in the cockpit: there is always something missing. The pilot has Jester, which is an amazing feat of software engineering by Heatblur, but it will be always a loyal subject of the front seater (excluding when he ejects…) and never takes the initiative, and it is not proactive. The RIO has Iceman, which is a bare-bone-practice-only AI that does not really do much besides turning and changing speed and altitude when instructed to do so (although there may be plans to expand its capabilities IIRC – don't quote me on that). Therefore, the pilot can fly and train a good chunk of the skills required to its role with Jester, but the RIO can't, and a pilot is required for the RIO to practice. Or, at least, that's what I often read on the internet, in various communities.

Personally, I spent the vast majority of my time training offline. If I have to quantify, for at least 95% of the time I spent in the cockpit I was with Mr

Iceman. How did I practice? The answer is simple, the **Mission Editor**, and I partially covered it already in the past.

21.1.1 TRAINING IN SP: VIDEO

I put together the following video in a couple of hours, so it does not go as in-depth as I wanted, but it should give you a couple of useful ideas.

Figure 523: RIO Training in SP Video. Click to open it (YouTube).

21.1.2 OVERVIEW OF THE SCENARIOS DISCUSSED

Three main topics are discussed in the video: basics, simplified BVR Timeline and Geometry.

BASIC CONCEPTS

The "basic stuff" is the most important series of concepts you can work on when you are a brand new virtual Radar Intercept Officer. An exercise as simple as observing an orbiting target, studying how the vector changes in TID GS and AS and how it disappears when Notching or in the Zero Doppler Filter (ZDF), can help to understand the limits and the strengths of the AWG-9: this is the very bedrock of the RIO job!

The exercise shown in the video is limited to TWS, but there is a lot more you can study. For example:

- effect of the aspect in P and PD mode;
- MLC on and off when feet wet and feet dry;
- quickly changing radar mode to maintain SA;

- change the altitude and the speed of the F-14 (in the video, both fighter and target are flying at the same speed);
- increase the range and see which radar mode spots the contacts first and understand why.

SIMPLIFIED TIMELINE

The setup shown in the video is extremely simple but allows you to practice the comms, get used to the avionics and the "content" of each step of the timeline (here is an old article of mine about it). Once you are satisfied with the basic setup you can shuffle things around by allowing the target to engage you, adding a wingman and try different "Sorts" or having the target slightly jinking and so on.

GEOMETRY: TARGET ASPECT DETERMINATION[136]

This is another very limited example of the many concepts related to the geometry you can practice. In this case, the determination of the Target Aspect using the BH → BB formula.

The formula just mentioned is the one I use the most, as in DCS the information provided by the controller is quite reliable, and it can be applied by calculating the BB manually, or by using the Bearing from the controller itself. However, since the AWG-9 returns the True Course of the target and not the Magnetic, the magvar has to be taken into account somewhere. The alternative is using the True FH obtainable from the TID.

Similar scenarios can be used to practice almost any aspect of the maths behind the geometry: you can calculate DOP, Cut, CC, observe the drift and so on. The series of articles related to the geometry is available here.

21.1.3 THE NEXT STEP?

The mission editor allows you to create almost any scenario. However, at some point, the lack of a pilot will prevent you from being able to practice efficiently. Nevertheless, even fairly advanced procedures can be profitably practised.

A few video examples can be found in Chapter 10.5.

21.2 NON CO-SPEED INTERCEPTS

The declassified and freely accessible documents cover only co-speed intercepts. This is a short study that aims to quantify the impact of the difference between VF14 and VTGT on the Collision Course.

136 This video predates the introduction of the TID second readout line that provides the Target Aspect.

As we have seen multiple times, the basic documentation (such as the P-825/17) covers only the co-speed intercepts. In such scenarios, the Collision Bearing is determined very easily by using the relation:

$$CB_{COSPD} = \frac{Cut}{2}$$

However, in DCS this is very rarely the case. Therefore, when the speed of the fighter (VF14) and the speed of the target (VTGT) are different (ΔV > 0), the relation is no longer applicable.

This simple study aims to quantify the difference between CB and CBCOSPD. In other words, help the RIO to better understand this situation by having an idea of how much, what he can expect and what he can do to compensate such difference.

Note: The CB is often referred to as CATA: Collision Antenna Train Angle. It makes sense since the CB is the ATA value when there is Collision.

Let's start from the beloved TID in Aircraft Stabilized mode, as it shows very clearly when Collision Course is established no matter ΔV. By comparing that angle and CBCOSPD, we can understand the magnitude of the impact of ΔV on CB.

21.2.1 TESTING SCENARIO

These are the parameters set for recreating the TID AS display below. In this scenario, the two variables are VF14 and VTGT.

- FH = 360°
- BH = 135°
- DTG = 135° (" α ")
- Cut = 45L
- DOP Left to Right

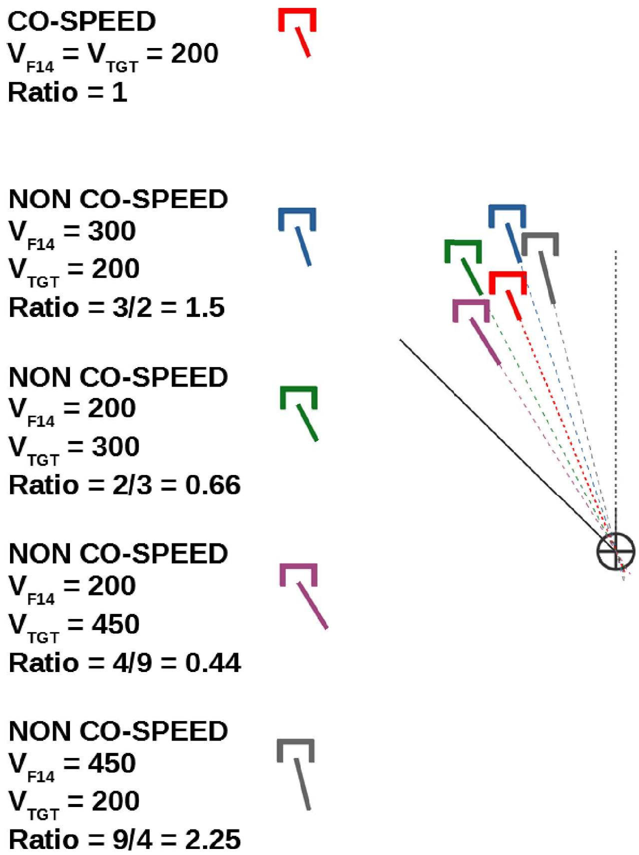

Figure 524: Non co-speed intercepts - Testing scenario.

Figure 524 clearly shows how the CB changes depending on the speed of the fighter and the bandit.

It is interesting to note how the Vector generated by aircraft having the same ratio displays the same angle, although the Vector's length is different.

For example, the Vector angle (and therefore the CB) of a situation where VF14 = 300 and VTGT = 200 is exactly the same of a scenario where VF14 = 450 and VTGT = 300:

$$\frac{300}{200}=\frac{450}{300}=1.5$$

21.2.2 CALCULATING THE ANGLES

The question is how we find the angle. The answer can be found in the geometry, by doing some poor man's reverse-engineering on the TID Vector:

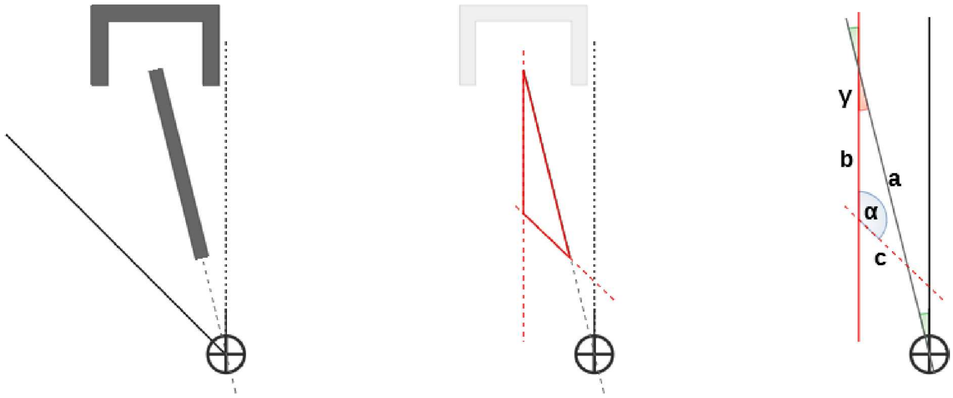

Figure 525: TID vector "reverse-engineered".

We already know that, then CB is established, the vector points towards the F-14 and the triangles defined by the vectors and the one defined by the headings and the CB are geometrically similar (my coolest discovery so far :p).

Let’s consider the third image. The thick black line is the FFP, the red thick line is the FFP used to construct the vector. Therefore, they are parallel. CB, the thinner black line that connects the vector to the F-14, is therefore cutting two parallel lines. The angles originated are congruent (“γ”, the green one, plus the red, which is the opposite angle). We also know b, c and α.

The Cosine rule allows to easily calculated the hypotenuse (the “length” of the Vector, “a“). From there, we can calculate γ:

$$a2=b2+c2-2bc*\cos(\alpha)$$

$$\cos(\gamma)=\frac{a2+b2-c2}{2ab}$$

I chucked the formulas on Google Spreadsheet (I can share the spreadsheet, but there’s really not much to see there) and then filled a table with different values of speed:

TGT SPD (c)	F-14 SPD (b)									DTG ►	α =	135
	200	250	300	350	400	450	500	550	600	650	700	750
200	22.50°	19.86°	17.76°	16.05°	14.64°	13.45°	12.43°	11.56°	10.80°	10.13°	9.54°	9.01°
250	25.14°	22.50°	20.34°	18.55°	17.04°	15.75°	14.64°	13.67°	12.82°	12.07°	11.40°	10.80°
300	27.24°	24.66°	22.50°	20.68°	19.11°	17.76°	16.59°	15.55°	14.64°	13.82°	13.09°	12.43°
350	28.95°	26.45°	24.32°	22.50°	20.92°	19.54°	18.32°	17.24°	16.28°	15.42°	14.64°	13.93°
400	30.36°	27.96°	25.89°	24.08°	22.50°	21.10°	19.86°	18.76°	17.76°	16.87°	16.05°	15.31°
450	31.55°	29.25°	27.24°	25.46°	23.90°	22.50°	21.25°	20.13°	19.11°	18.19°	17.35°	16.59°
500	32.57°	30.36°	28.41°	26.68°	25.14°	23.75°	22.50°	21.37°	20.34°	19.41°	18.55°	17.76°
550	33.44°	31.33°	29.45°	27.76°	26.24°	24.87°	23.63°	22.50°	21.47°	20.52°	19.65°	18.85°
600	34.20°	32.18°	30.36°	28.72°	27.24°	25.89°	24.66°	23.53°	22.50°	21.55°	20.68°	19.86°
650	34.87°	32.93°	31.18°	29.58°	28.13°	26.81°	25.59°	24.48°	23.45°	22.50°	21.62°	20.81°
700	35.46°	33.60°	31.91°	30.36°	28.95°	27.65°	26.45°	25.35°	24.32°	23.38°	22.50°	21.68°
750	35.99°	34.20°	32.57°	31.07°	29.69°	28.41°	27.24°	26.15°	25.14°	24.19°	23.32°	22.50°

Figure 526: CB Variation, Cut 45°.

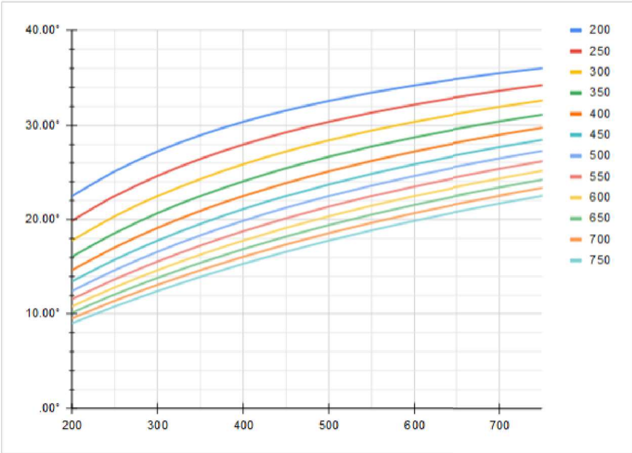

Figure 527: CB Variation, Cut 45° - Chart.

Then determined ΔCB:

CB Var	200	250	300	350	400	450	500	550	600	650	700	750
200	.00°	2.64°	4.74°	6.45°	7.86°	9.05°	10.07°	10.94°	11.70°	12.37°	12.96°	13.49°
250	-2.64°	.00°	2.16°	3.95°	5.46°	6.75°	7.86°	8.83°	9.68°	10.43°	11.10°	11.70°
300	-4.74°	-2.16°	.00°	1.82°	3.39°	4.74°	5.91°	6.95°	7.86°	8.68°	9.41°	10.07°
350	-6.45°	-3.95°	-1.82°	.00°	1.58°	2.96°	4.18°	5.26°	6.22°	7.08°	7.86°	8.57°
400	-7.86°	-5.46°	-3.39°	-1.58°	.00°	1.40°	2.64°	3.74°	4.74°	5.63°	6.45°	7.19°
450	-9.05°	-6.75°	-4.74°	-2.96°	-1.40°	.00°	1.25°	2.37°	3.39°	4.31°	5.15°	5.91°
500	-10.07°	-7.86°	-5.91°	-4.18°	-2.64°	-1.25°	.00°	1.13°	2.16°	3.09°	3.95°	4.74°
550	-10.94°	-8.83°	-6.95°	-5.26°	-3.74°	-2.37°	-1.13°	.00°	1.03°	1.98°	2.85°	3.65°
600	-11.70°	-9.68°	-7.86°	-6.22°	-4.74°	-3.39°	-2.16°	-1.03°	.00°	.95°	1.82°	2.64°
650	-12.37°	-10.43°	-8.68°	-7.08°	-5.63°	-4.31°	-3.09°	-1.98°	-.95°	.00°	.88°	1.69°
700	-12.96°	-11.10°	-9.41°	-7.86°	-6.45°	-5.15°	-3.95°	-2.85°	-1.82°	-.88°	.00°	.82°
750	-13.49°	-11.70°	-10.07°	-8.57°	-7.19°	-5.91°	-4.74°	-3.65°	-2.64°	-1.69°	-.82°	.00°

Figure 528: Δ CB, Cut 45°.

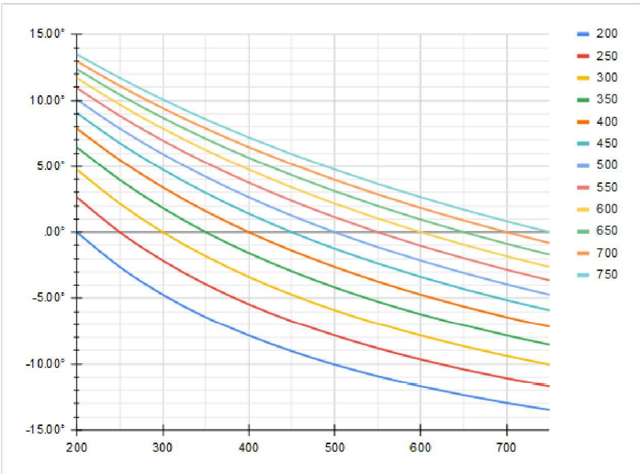

Figure 529: Δ CB, Cut 45° - Chart.

CB Var	200	250	300	350	400	450	500	550	600	650	700	750
200	.0%	11.7%	21.0%	28.6%	34.9%	40.2%	44.7%	48.6%	52.0%	55.0%	57.6%	59.9%
250	-11.7%	.0%	9.6%	17.6%	24.3%	30.0%	34.9%	39.2%	43.0%	46.4%	49.3%	52.0%
300	-21.0%	-9.6%	.0%	8.1%	15.1%	21.0%	26.3%	30.9%	34.9%	38.6%	41.8%	44.7%
350	-28.6%	-17.6%	-8.1%	.0%	7.0%	13.2%	18.6%	23.4%	27.6%	31.5%	34.9%	38.1%
400	-34.9%	-24.3%	-15.1%	-7.0%	.0%	6.2%	11.7%	16.6%	21.0%	25.0%	28.6%	31.9%
450	-40.2%	-30.0%	-21.0%	-13.2%	-6.2%	.0%	5.6%	10.5%	15.1%	19.1%	22.9%	26.3%
500	-44.7%	-34.9%	-26.3%	-18.6%	-11.7%	-5.6%	.0%	5.0%	9.6%	13.7%	17.6%	21.0%
550	-48.6%	-39.2%	-30.9%	-23.4%	-16.6%	-10.5%	-5.0%	.0%	4.6%	8.8%	12.6%	16.2%
600	-52.0%	-43.0%	-34.9%	-27.6%	-21.0%	-15.1%	-9.6%	-4.6%	.0%	4.2%	8.1%	11.7%
650	-55.0%	-46.4%	-38.6%	-31.5%	-25.0%	-19.1%	-13.7%	-8.8%	-4.2%	.0%	3.9%	7.5%
700	-57.6%	-49.3%	-41.8%	-34.9%	-28.6%	-22.9%	-17.6%	-12.6%	-8.1%	-3.9%	.0%	3.6%
750	-59.9%	-52.0%	-44.7%	-38.1%	-31.9%	-26.3%	-21.0%	-16.2%	-11.7%	-7.5%	-3.6%	.0%

Figure 530: Δ CB, Cut 45° (%).

21.2.3 PRACTICAL TEST

A simple test to check if the model makes sense:

Altitude: Co-altitude, value non-factor;

VF14 = 400;

VTGT = 200;

I set up the geometry a bit randomly, let's see what the TID said:

Figure 531: Non co-speed intercepts - Practical test.

True Course: 167

True Heading: 19

DTG = 148°

Cut = 32° → CBCOSPD = 16°

However, due to the speed difference, CB must be adjusted. The model should tell us how much: