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Contents

Introduction

Unmanned Air Vehicles (UAVs) are an integral part of the U.S. fighting force. UAVs are being used extensively in Iraq and Afghanistan to provide intelligence data, including real time streaming video, to commanders and troops on the ground. Recently, some UAVs have had weapons included in their payload. These weaponized UAVs – sometimes called Unmanned Combat Air Vehicles (UCAVs) – have had spectacular success in taking out terrorists. In 2004, the CIA executed a pinpoint strike in Yemen against a top al-Qaeda operative using a Hellfire air-to-ground missile launched from a Predator UAV.

Predator UAV carrying a Hellfire missile

UAVs are often used to support strike missions by other aircraft. The US Army's MQ-5 Hunter UAV is used in Iraq to direct Apache Longbow helicopters as they engage insurgents.

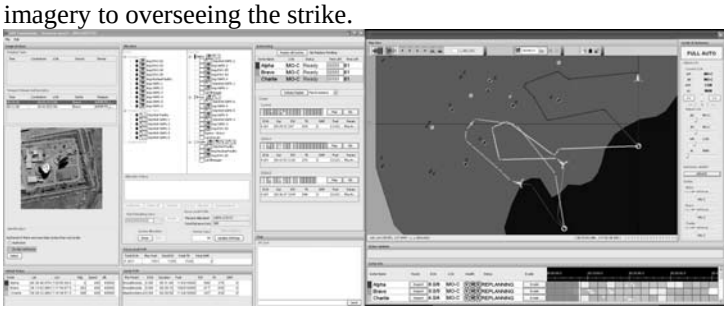
Smaller UAVS like the RQ-11 Raven, which can be carried in a backpack and hand launched, help ground troops “see over the hill.” These short-range UAVs transmit video of the surrounding area, showing the location of enemy fighters

and non-combatants. This helps troops to stay safe and to avoid collateral damage.

UAVs are beginning to be used in non-military operations. Police departments are starting to use UAVs to provide intelligence information to officers on the ground. The U.S. Forest service is using UAVs in fire fighting operations. Similar to the support role UAVs play in military strike missions, UAVs can provide video and imagery of fire locations to help direct water tankers.

Military-themed computer games provide an important bridge to real world applications. In addition to use by gamers, this technology can be used to train military UAV operators - who are often gamers themselves.

The UAV Commander: Control Station Simulator game provides access to multi-UAV mission control station (MCS) technology that is more advanced than many UAV control stations currently in use. Unlike most UAV control stations, UAV Commander allows you to manage *multiple* UAVs. You will direct missions such as those performed by the Hunter and the Predator. But with multiple vehicles, you manage the whole operation, from collecting the imagery to overseeing the strike.



As UAV Commander, you are a member of an elite team. UAV commanders need a mix of talent, skill, and experience. Although automated tools generate plans, the UAV commander plays an essential role in optimizing mission effectiveness. During mission

execution the UAV commander must maintain situation awareness by monitoring the progress of the mission and checking for changes in the environment and other new information. A UAV commander must have quick reactions, but must also exercise good judgment, which is the product of experience. Experience will help you understand the strengths and limitations of the automated MCS tools. The success of your mission will depend on your ability to monitor the situation, to react quickly, and to make good decisions.

Your mission, if you decide to accept it, is to use your UAVs to search for and attack targets. As the UAVs fly their search missions, you monitor the images you take and the health and status of the vehicles. The vehicles are not authorized to shoot without your consent. You are to command your UAVs to find and verify two targets. The MCS displays the UAV target imagery for you to review. The targets are mobile and high value. Because of the chance of escape, the strike mission must be planned and executed quickly. While you check the imagery to verify the target and to check for the possibility of collateral damage, the autonomous planning modules generate route plans for your UAVs. Each of the targets must be imaged to pinpoint their locations and verify the objectives, then each be struck with two weapons, and finally there must be post-strike bomb damage assessment (BDA) of both targets. The MCS displays the plans generated by the automated tools, and you give the plans a sanity check before authorizing the strike. After the mission, you inspect the BDA report. Because of the importance of the targets, you may have to order two of your UAVs to take a second look. Once you are satisfied that the targets have been destroyed, you order your UAV team to the next hot area.

Getting Started

Installation and Setup - Installing UAV Commander

UAV Commander is supported in both Windows and Linux environments.

In Windows, you will have the option to run UAV Commander from the CD-ROM/DVD drive or to install the software by running Setup.exe.

In Linux, you will also be able to run the software from the CD-ROM/DVD drive, or install it onto the system by running Setup.bin.

Starting UAV Commander

UAV Commander should automatically run on most systems from the CD-ROM/DVD drive. If installed onto the local hard disk, run the application by double clicking on the desktop icon, selecting the application from the start menu, or navigating to the install directory on your system and running the batch/shell file.

Retrieving a Password

Your UAV Commander product will likely run out of the box without any issues. If you receive a password box while attempting to run UAV Commander, please use your web browser and navigate to http://www.orca1.com/uav_commander.htm and follow the instructions.

Running UAV Commander

When you first load UAV Commander, we will auto-detect your screen resolution(s). UAV Commander supports both single monitor and dual monitor setups. When you run the simulated ground control station, an appropriate screen layout will be chosen for you.

Once inside UAV Commander, you will have multiple options to choose from, including: (1) **Training**, (2) **Mission Select**, (3) **High Scores,** and (4) **Quit**.

If you are new to UAV Commander, press the **Training** button to launch a Training mission. This mission will introduce you to many of the different types of activities that you may be faced with during a real mission. Before your mission begins, you will be taken to the Briefing Room.

Inside the Briefing Room, you will be briefed on the current mission. The background behind this theater of operation will be displayed, along with your mission objectives. Normally you will need to select a mission difficulty and enter your pilot name to proceed.

Once you start the mission, your briefing room will minimize and your simulated ground control station will load. Press the green start button located above the map display to begin.

If you are familiar with the UAV Commander interface, feel free to proceed to **Mission Select** and choose a mission.

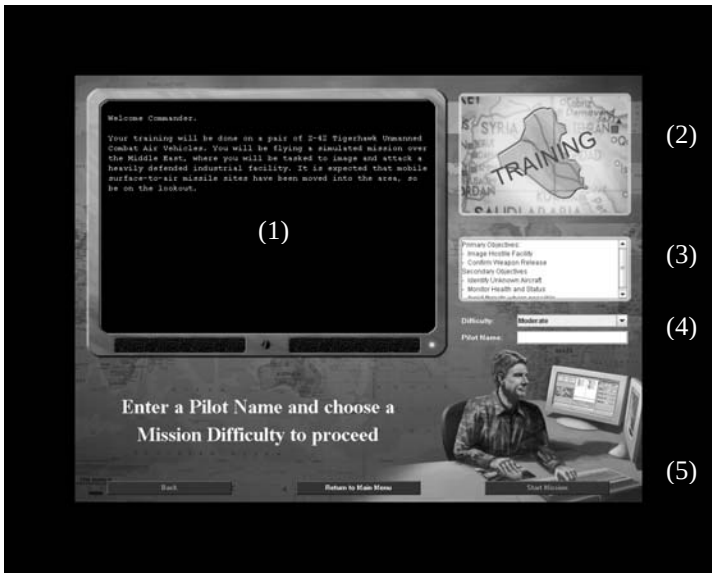
Receiving a Score

Following the completion of each mission, you can view your effectiveness regarding operator performance, decision quality, and penalties. Your score is out of 1000 points, and the top scores for each mission (other than the Training mission) are saved and can be viewed in the High Scores menu.

Prepare for Combat

You are now ready to embark upon your new role as a UAV Commander. Proceed to the Training Mission to prepare for the missions ahead…

Briefing Room



(1) Mission Briefing, (2) Geographical Location, (3) Objective Summary, (4) Name and Difficulty, (5) Start Mission button

Description

The Briefing Room will bring you up to speed on the mission you are tasked to perform.

Mission Briefing

Your mission briefing will give you information regarding the region and the current state of affairs you will be flying into. Friendly aircraft and equipment will be described along with primary and secondary objectives. Known and predicted hostile threats in the region may be discussed. Additional information pertinent to the mission may also be addressed including special rules of engagement and/or other factors such as weather.

Geographic Location

You will be provided with a map showing your current theater of operations.

Objective Summary

Your objective summary will inform you of your primary and secondary objectives that you are tasked to perform during this mission. Both primary and secondary objectives are weighted evenly regarding objectives achieved for scoring purposes.

Pilot Name and Mission Difficulty

A pilot name must be entered and a difficulty rating chosen before the mission can begin. Enter your name and select the difficulty rating for the mission. The **Start Mission** button will become available once a pilot name has been entered.

Start Mission and Mission Analysis

Press the **Start Mission** button to load the scenario and begin your mission. At this time, the Briefing Room will disappear and the UAV Commander simulated ground control station will be displayed.

Available only after playing a mission and in place of the **Start Mission** button, selecting **Mission Analysis** will give you insight into your performance and quality of decisions made during the mission. Your mission will be scored out of a possible 1000 points.

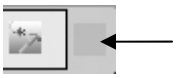
Using the GUI Interface

UAV Commander has a rich variety of displays that are important for awareness of what's happening and to aid in good decision making.

Interactive Displays

The following displays require you to do something.

The Start Button



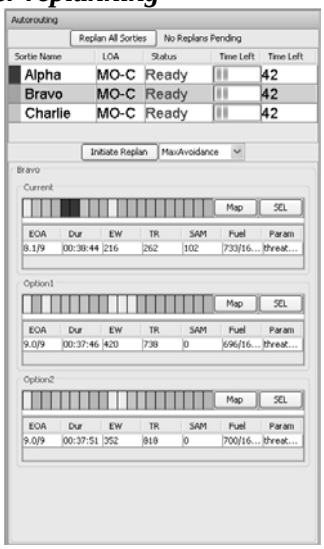
When you are ready to begin the simulation, click the green button on top of the map display.

Image Analysis/ Weapon Release Authorization

When one of your UAVs takes a picture, go to the Image Analysis panel. This panel displays the target imagery that the UAV has collected. For each image, it will display the time it was taken, a countdown time (the newer the image the more valuable/accurate, and at some point it will expire), the level of autonomy (LOA) – more on this later, the source or UAV that took the image, and the sensor used to take the image. Click on a row to display the image. In the lower section called Identification, there will be a question and some choices. Using the radio buttons, select the right answer, and click Select to lock in your answer.

The interface for weapon release is very similar to image analysis. When one of your UAVs is ready to release a weapon, go to the Image Analysis panel and look at the Weapon Release Authorization section. There is a time and countdown. Here, countdown is important because the weapon is about to be dropped and you must authorize its release before the countdown ends, or otherwise nothing happens. Again it displays the LOA and sortie that took the image and the weapon to be used. Click on a row to display the image. In the lower section called Identification, there will be a question and two choices, “Authorize” or “Do Not Authorize”. Use the radio buttons to select “Authorize” if true, or “Do No Authorize” if false, and click Select to lock in your answer.

Autorouting/Choosing routes after replanning



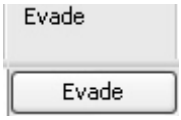
The Autorouting panel allows you to choose routes for the UAVs under your control. Routes are generated real-time using complex algorithms, which take into account your vehicles’ capabilities and try to accomplish mission tasks while avoiding threats. Replanning is triggered either when pop-up threats appear, your vehicle status changes, or you can initiate new routes by clicking on the Replan All Sorties button at the top of the panel. It is divided into two parts, the top and bottom. When a replan is occurring, the table at the top will display rows, one for each of your UAVs. The information displayed is Sortie Name, LOA, Status, and Time Left. When new routes are being generated, the status is Pending; when they are done, the status is Ready. Time left is the time you have remaining to choose a route for your UAV. If time runs out, your UAV will

fly its current route. When the status is ready for a UAV, click anywhere on the row and look at the bottom part of the panel. The bottom part displays your current route, which is always the first one, and options, which are below. There is information to help you choose a good route. The timeline is shown for all routes for comparison. In addition, the expected number of objectives achieved (EOA), the duration, the total number of seconds exposed to Early Warning (EW) radars, tracking radars, and Surface-to Air Missiles (SAMs) are shown. Finally, the fuel used for each route and the route parameters used are shown. Route parameters are used by the autorouter to generate a route. Some parameters may generate a better route for the given situation. You can see the route displayed on the map by clicking the Map button. Option (non-current) routes are shown with a dotted-line on the map. To select a route, click Sel. For more information on how to select a quality route, see the Tips chapter at the end of the manual.

Vehicle Health and Status

Three circular gauges labeled V, W, and S represent your vehicle, weapon systems, and sensor systems. Green indicates that the system is fine. Red indicates that it's broken. Yellow is a warning that alerts you to potential problems. Click on a gauge when it turns yellow.

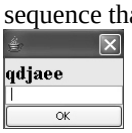
Evade



This very important button simulates evasive maneuvers. When a SAM shot occurs on one of your UAVs, click this button on the vehicle affected. This will tell your UAV to initiate evasive maneuvers which will increase its chance of survival.

Unidentified Plane Identification

At some point in a scenario, an unidentified plane may pop up on the map. It will be represented by an aircraft icon. When you spot this, click on the icon and then type in the random character sequence that you see.



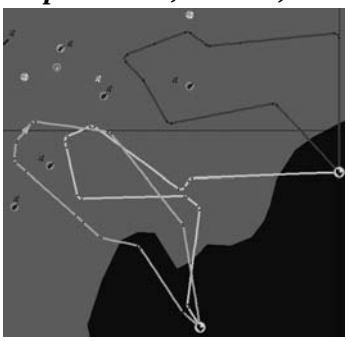
SAGAT

At some point in a scenario, you may run into this test. The Situation Awareness Global Assessment Technique or SAGAT, provides an objective measure of your situation awareness by freezing the simulation, blanking the screen, and asking you a series of questions about your current understanding of the situation. These questions may cover a variety of situation awareness levels including perception (awareness of basic cues), comprehension (combining, interpreting, processing, and storing information), and projection (taking what one has perceived and understood and forecasting future events).

Non-Interactive Displays

The following displays provide useful information.

Map – Sorties, Threats, Other icons/symbols



As UAV Commander, the map is one of your most important tools. It lets you know at a quick glance what is going on.

The routes are represented by colored lines; each route is a different color.

On a route you may notice green lines that end in an arrow. These are waypoint segments, and the route's path must fly over them. These represent ingress and egress paths.

There are icon buttons on top of the map that you can click to enable more graphics to be displayed on the map. By default these are initially disabled. These include the ability to see:

- Exposure fans – These fans emanate from the threat to the route in the color of the threat and show the period of time that the route is exposed to the threat.
- Mission event icons – These icons are on the route and show when events begin and end. In particular, there are icons for the beginning and end of an image, the beginning and end of a weapon release, the beginning and end of a waypoint segment, and when a must fly occurs.
- Objective fans – The fans emanate from the route to the object that an objective is being performed on, such as a target or threat. The fans show when an image begins and ends and when a weapon release begins and ends.

Threats are represented by icons on the map. Yellow radars are EW radars, orange radars are tracking radars, and the missile icons represent SAMs. When pop-up threats occur, a solid red circle will surround the threats for a short period of time. When SAMs fire, an icon will appear on the map where the SAM fired for a few seconds.

UAVs are represented by aircraft icons. These will move along the route as the simulation progresses.

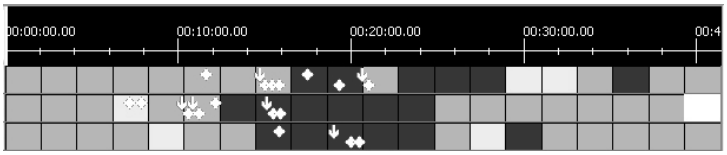
Airbases, where your UAVs take off and land, are represented by an icon that resembles an airport tower or a military icon symbol.

A green triangle represents a target.

Two different colored bull's eyes icons represent mission tasks. These are tasks either performed on a target or a threat. A blue bull's eyes icon represents an imaging task. A red bull's eyes icon represents a weapon release task.

Another icon on the map will represent an unidentified aircraft. This icon will look like an aircraft and will be used for the unidentified plane identification task.

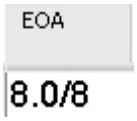
Timeline



Each vehicle has a timeline associated with it. The timeline is divided into several colored boxes and is designed to show you how safe or dangerous the route is for each period of time. The colored boxes represent the worst exposure to a kind of threat for that period of time. SAMs are worse than radars, and tracking radars are worse than EWs. Green means no exposure, white means the aircraft is not in the air at that time, yellow is exposure

to EW radars, orange is exposure to tracking radars, and red is exposure to SAMs. For example, a red box means that for that period of time, your vehicle was exposed to at least one SAM. But it does not necessarily mean it wasn't exposed to EWs or tracking radars. If you click on any box, a more detailed, blown up timeline showing exposure for that period of time appears, and that portion of the corresponding route will be highlighted on the map. In addition, there are icons on the timeline that represent when imaging objectives and weapon release objectives are accomplished. Mousing over them will pop up a tooltip with their task name. The icons on the top half of the box represents weapon release events for weapon release authorization (which includes the related pre-release imaging); the bottom half represents imaging events for image analysis.

EOA



EOA is a metric that stands for expected number of objectives achieved. Objectives include weapon release, imaging, must fly, CAP, and waypoint segments. The numerator is the expected number of objectives achieved. The denominator is the total number of objectives.

Status

The status column shows you what is happening and can prompt you to act. The follow messages could appear:

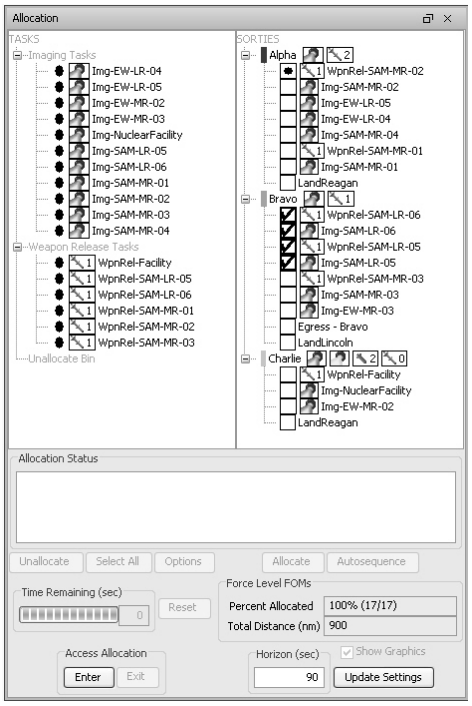
- **OK** – No action is needed.
- **REPLANNING** – Your sorties are in the process of autorouting or have completed autorouting and your attention is required. This could have been initiated with

pop-up threats. Go to the Autorouting panel and make decisions on which routes are best.

- **REALLOCATING** – Either you've entered the allocation panel or one or more of your vehicles needs to be reassigned mission tasks.
- **SAM FIRED!** – A SAM has launched a missile at your vehicle! Take action quickly by clicking the appropriate Evade button.
- **EVADE** – You have clicked the Evade button for this UAV and have instructed it to start evasive maneuvers.

Allocation

Allocation assigns tasks to sorties to achieve force application goals. The assignment process considers vehicle resources such as fuel and available weapons and sensors, assignment costs such as vehicle value and probability of survival, and target values. This panel's display shows the following.



The TASKS tree consists of all allocatable tasks in the scenario. The circle at the

beginning of each line in the TASKS tree indicates whether that task has been allocated or not. If the circle is black then it is allocated, otherwise it is unallocated.

The icon next to the circle indicates the resource type. For weapon release tasks a number is also displayed next to the icon, which indicates how much of that resource is required for that task.

The SORTIES tree consists of all sorties in the scenario and their mission tasks lists. The color in front of each sortie's name reflects its route color on the map. The icons to the right of the sortie's name reflect its sensor suite and weapon payload. The number next to the weapon resource indicates how many weapons that sortie can still allocate.

The tasks beneath each sortie reflect its ordering in that sortie's mission task list. Each task still displays its resource icon but there is an additional square at the beginning of each task. That square indicates whether the task has been completed (a checkmark) or is within the planning horizon (a circle). If the task has been completed or is in-progress then the task cannot be reallocated at that point. If a task name is colored red then that means the sortie does not have the resources to achieve that task.

Unallocated tasks can be dragged from the TASKS tree to any mission task list in the SORTIES tree. Multiple tasks can be selected by holding down the shift or control key. Note, though, once allocated, tasks can no longer be dragged from the TASKS tree. Once in the SORTIES tree (and thus allocated), any task can be dragged to another position in the same mission task list or to a different mission task list. As tasks are moved between sorties the available resources may change for each sortie. Tasks may be unallocated by dragging one or more tasks from the SORTIES tree to the Unallocated Bin in the TASKS tree.

To access allocation, click the Enter button. Before that button is pressed you will be unable to modify the mission task lists. Once

allocation is entered, a countdown will begin using the value specified in the planning horizon. However, if a clock is not running, then the time will not decrement. This planning horizon defines what tasks are to be included as in-progress and therefore unallocatable. You can restart this planning horizon by clicking the Reset button or may exit by clicking the Exit button. Note that allocation will be automatically exited once the planning horizon has been surpassed.

The Allocate button causes any selected tasks and sorties to be allocated. To select all tasks and sorties in the scenario click the Select All button. Feedback from the allocator is displayed in the Status window. If the allocation is successful, the tasks will be automatically moved to their assigned sortie's mission tasks lists.

The Autosequence button optimizes the individual sortie's mission task lists for any selected sorties. Feedback for this operation is also displayed in the Status window.

Selecting a sortie and clicking the Unallocate button causes all the tasks assigned to that sortie to be unallocated. Selecting individual tasks and clicking the Unallocate button will cause those tasks to become unallocated.

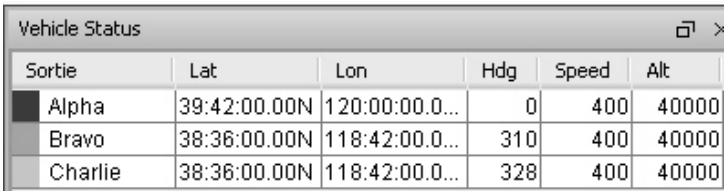
Any changes that you make to the mission task lists are not permanent until you **replan** the sorties (by clicking the Replan All Sorties button in the Autorouting panel). To reset the mission task list to their original values before modification, click the Reset button.

The force level FOMS show the percent of tasks allocated and the total distance of all mission task lists. The total distance consists of the straight line distances between each task in all of the sortie's mission tasks lists.

When the Show Graphics checkbox is enabled then graphics will be displayed on the map when interacting with the TASKS tree

and the SORTIES tree. If a task is selected in either of the trees then the corresponding task will be highlighted on the map. If a sortie is selected then a preview of its tie-up (mission task list) shown in dotted lines will be displayed on the map.

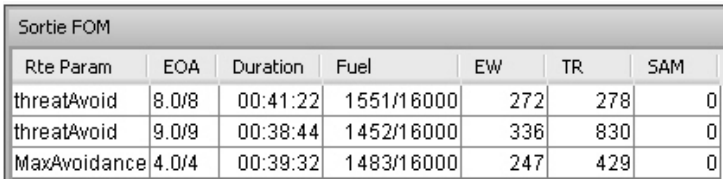
Vehicle Status


Vehicle Status

Sortie	Lat	Lon	Hdg	Speed	Alt
Alpha	39:42:00.00N	120:00:00.0...	0	400	40000
Bravo	38:36:00.00N	118:42:00.0...	310	400	40000
Charlie	38:36:00.00N	118:42:00.0...	328	400	40000

This panel shows you the UAVs you are controlling and information about them. For each UAV, it displays its location in latitude and longitude, its heading in degrees, its speed in knots, and its altitude in feet.

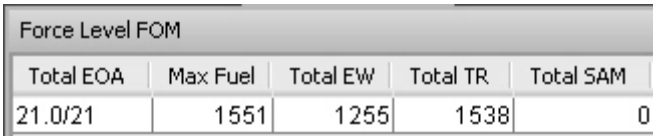
Sortie FOM


Sortie FOM

Rte Param	EOA	Duration	Fuel	EW	TR	SAM
threatAvoid	8.0/8	00:41:22	1551/16000	272	278	0
threatAvoid	9.0/9	00:38:44	1452/16000	336	830	0
MaxAvoidance	4.0/4	00:39:32	1483/16000	247	429	0

This panel shows you figures of merit (FOM) for each individual UAV that you control. The order is the same ordering as the vehicle statue panel. In each row, the FOMs shown are the route parameters used to generate the route, the EOA, the route duration remaining for the vehicle since the last autoroute, the fuel to be used out of the fuel capacity of the vehicle, and total number of exposures in seconds for EW radars, tracking radars, and SAMs.

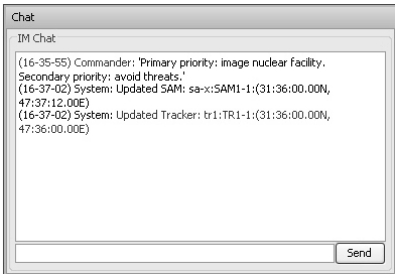
Force Level FOM


Force Level FOM

Total EOA	Max Fuel	Total EW	Total TR	Total SAM
21.0/21	1551	1255	1538	0

This panel shows you the aggregate figures of merit for all the UAVs under your control. It shows the total EOA, the highest amount of fuel to be used by a sortie that you control, and the total number of seconds that all of your UAVs are exposed to EWs, tracking radars, and SAMs.

Chat



This IM window allows you to chat with your commander. Your commander will send you periodic messages about the mission. It also displays system messages.

Other Displays

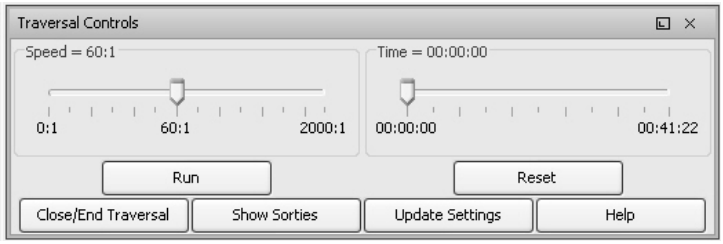
Traversal

This tool allows you to get even more insight into what's going on. It allows you to project your vehicles into the future and allows you to see why your vehicles are exposed to threats via vehicle threat templates (see Appendix for more information).

To bring up traversal, click the Traversal Controls button.

To project your vehicle into the future or even go back into the past, you'll need to click the sync toggle button to prevent syncing

with the simulation (initially traversal is synced with the simulation by default).



The Traversal Controls panel allows you to project your UAVs forward or backward in time along the route by dragging the time slider back and forth. The slider bar under Speed changes the pace (1:1 represents real time, 2:1 represents twice the speed of real time, and so forth.)

The Traversal Template Display panel allows you to view vehicle threat templates on the map. Select sorties and associated threat types you want to see (multiple selection can occur by holding down the Ctrl button) and click the Apply button.

Once you are done with traversal, you'll want to sync with the simulation again, so click on the sync toggle button. To clear the projected ghost vehicles and vehicle threat templates by shutting down Traversal, click the Close/End Traversal button.

Levels of Autonomy

There are levels of autonomy for the system as well as for the four main tasks: autorouting/replanning, image analysis, weapon release authorization, and allocation. These levels define how the system (computer) will aid you in accomplishing your tasks. Levels of autonomy are indicated by the following acronyms:

- MAN (Manual)
- MO (Multiple Options)
- MO-C (Multiple Options Consent)
- CON (Consent)
- MO-V (Multiple Options Veto)
- VET (Veto)
- AwF (Automatic with Feedback)
- AUTO (Fully Automatic).

These LOA may have slightly different effects due to the differences in the tasks, but generally, these are what the autonomy levels mean to you in dealing with your tasks. In MAN LOA, the system has you make the decision. In MO LOA, the system gives you multiple options to consider, and you must make the final decision. In MO-C LOA, the system presents a pre-selected suggestion to multiple options. You may accept it or choose another option, but if time expires no action is taken. In CON LOA, the system provides you with one option which is the system's suggestion. You can accept or reject, but if time expires no action is taken. In MO-V LOA, the system presents a pre-selected suggestion to multiple options. You may accept it or choose another option, but if time expires the pre-selected suggestion is accepted as the choice. In VETO LOA, the system provides you with one option which is the system's suggestion. You can accept or reject, but if time expires the pre-selected suggestion is accepted as the choice. In AwF LOA, a single option is presented which is the system's choice. You may acknowledge the selection. In AUTO LOA, the system automatically takes action.

Theaters of Operation

United States of America

Expected Difficulty – Easy

As a UAV Commander, you have been tasked to support the Federal Bureau of Investigation and Department of Homeland Security, along with other un-named agencies, in an anti-terrorist raid in California. Recent reports suggest a terrorist organization has gathered heavy arms in a compound outside the Los Angeles area. Area surveillance needs to be accomplished before people on the ground can safely enter the area. It is suspected that the terrorist organization contains small arms and potentially shoulder launched anti-aircraft missiles.

North Korea

Expected Difficulty – Easy

North Korea has turned its back on the ongoing nuclear arms talks. Recent intelligence suggests that North Korea has built a new missile capable of reaching multiple allies, and that this missile has nuclear capabilities. You have been tasked to take a pod of UCAVs deep into enemy territory and eliminate the threat posed by the new system, and while you're in the area remove Pyongyang's nuclear

capability for the foreseeable future.

Iran

Expected Difficulty – Moderate

Iran has recently begun openly supporting the sect warfare occurring in Iraq, and its forces have made the bold move of becoming directly involved in skirmishes along the Iraqi-Iranian border. As a move to deter future involvement in this manner, you have been tasked to strike a number of strategic objectives behind enemy lines to deter future cooperation with militant groups inside Iraq. Your aircraft will be based out of friendly locations inside Iraq, however due to hostilities with various groups potentially allied with Iran; you can expect some resistance on both sides of the border.

Syria

Expected Difficulty – Moderate

Due to new attacks by Israeli aircraft against Hezbollah targets in Lebanon, Syria has made a move to mobilize forces towards Israel. Aircraft from Syria have hit northern Israeli installations in the last 24 hours. You are tasked to monitor Syrian troop movements towards Israel while diplomats attempt to cool things down.

If talks break down, you will be ordered to begin attacking hostile supply lines and delaying enemy troop movements.

China

Expected Difficulty – Hard

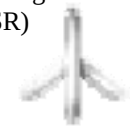
In a surprise move, China has attempted to take Taiwan by force. You have been tasked to provide a counter-strike into Chinese territory to weaken their supply and logistics capabilities supporting their military campaign. Multiple UCAVs are available under your control to strike a number of primary and secondary targets, ranging from military assets to power plants and industry. It is expected that there is a very strong integrated air defense network deterring aircraft from entering this region.

Assets

Unmanned Aircraft

Z-26 Zura

The Z-26 Zura is an unmanned air vehicle specializing in Intelligence, Surveillance, and Reconnaissance (ISR) missions. Equipped with state-of-the-art sensor systems and a stealthy signature, the Zura can sneak in behind enemy lines and get the imagery and data needed to support friendly forces in the region. The Zura is equipped with both synthetic aperture radar (SAR) and electro-optical / infra-red (EO/IR) sensor systems providing versatility for various tasks it may be assigned.



Z-15 Firebird

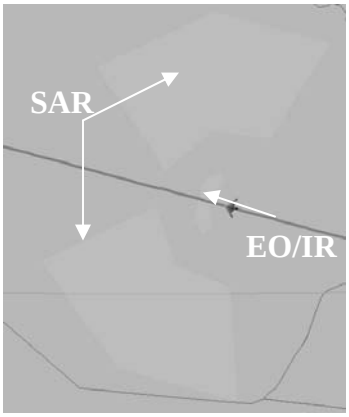
The Z-15 Firebird is an unmanned combat air vehicle equipped with standoff weapons systems. Designed as an autonomous combat aircraft, its primary role is deep strike into hostile territory. The Firebird is significantly faster than the Zura and is equipped with both long range and short range standoff weaponry.

Z-42 Tigerhawk

The Z-42 Tigerhawk is a multi-purpose unmanned combat air vehicle capable of handling the toughest of tasks. Equipped with both a strong sensor suite and a full array of weapons, the Tigerhawk is prepared to handle just about any mission sent its way. The Tigerhawk has the same sensor suite available on the Zura, with a similar weapon suite to the Firebird. The Tigerhawk is designed to penetrate enemy air defenses, find its targets using its superior sensor suite, and then be able to effectively prosecute the targets using its standoff weaponry.

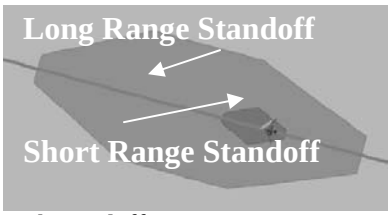
Sensor Systems

SAR Sensor
A synthetic aperture radar sensor is very capable at most altitudes and is nearly unaffected by weather patterns in the area. The available area where a SAR can see is much larger than its EO/IR counterpart.



EO/IR Sensor
The electro-optical / infra-red sensor system is much more limited than the SAR. The EO/IR sensor may be affected by weather and has a much smaller viewable area requiring the vehicle to get closer to its target before taking the image.

Weapon Systems



Standoff Weapons
Standoff weapons have both a long range and short range version, primarily varying in their weapon footprint. The Firebird and Tigerhawk are both commonly equipped with standoff weaponry.

Gravity Weapons
Gravity Weapons require the aircraft to fly near/over their target. Both the Firebird and Tigerhawk can be equipped with gravity weapons.

Threats

These are the kinds and types of threats you will be facing as UAV Commander.

EW Radars

Early Warning radars are threats that alert other threats in sites and/or nets about the presence of your vehicles. The following are EW radar types you'll face in the scenarios:

- EW-MR – These are medium range radars.
- EW-LR – These long range radars are considerably more dangerous.

Tracking Radars

Tracking radars are threats that usually have a smaller beam but once they spot your vehicle, they can track its location. They are the "eyes" of SAMs, so when they track a vehicle long enough, SAMs can fire. The following are tracking radar types you'll face in the scenarios:

- TRKR-SR – These are short range radars.
- TRKR-LR – These are more powerful long range radars. Be wary of these.

SAMs

Surface-to-Air Missiles are the most dangerous threats your UAVs will face. SAMs are the shooters, and they will launch missiles that can destroy your vehicles if you are in their kinematic range and their tracking radars have tracked your vehicles long enough. The following are SAM types you'll face in the scenarios:

- SAM-MR – These SAMs may be medium range, but they are still dangerous.
- SAM-LR – The most dangerous of all threats, the long range SAMs are very deadly.

Tips

- Be alert! There are several panels that you need to keep an eye on. Never focus too long on just one panel as you could ignore important events that pop up.
- Anticipate! The timeline shows you valuable information. It shows you future events: when imaging and weapon releases will occur. Knowing when they occur will allow you to anticipate when to do the image identification and weapon release authorization tasks. It also shows you your UAV(s) exposure to threats. If there are red squares, you know there's danger and you can be more prepared for possible SAM shots.
- And how would you know for sure there are SAM shots? Look at the EOA. If an UAV has an EOA less than 100%, such as 4.9/8, you know for sure SAM shots are coming, and they will occur some time while the UAV is in the red squares on the timeline. So get ready to click the Evade button!
- Choose quality routes! Better route selection after a replan will result in less opportunity for SAM shots so you don't have to worry about that. The goal is to minimize red boxes and maximize green ones. Orange is worse than yellow. A general rule of thumb is if the number of exposure squares is equal for different routes, you want to choose the route that separates them. So a route with five consecutive red boxes is worse than one with five red boxes but has some other colored squares between them. You can also compare the total number of seconds of exposure. Finally, compare the EOA. The higher the EOA, the better the route.
- Speed in response is as important as quality of response. Clicking Evade as soon as a SAM shot is fired is essential. You want to keep an eye out for the unidentified plane event and respond as soon as possible. You also need to acknowledge vehicle health and status changes quickly.

Appendix

Vehicle Threat Templates

When planning a route for an aircraft over hostile territory, it is of fundamental importance to know where and when that aircraft can be detected by radar or shot down by enemy fire. In UAV Commander, this knowledge is accessible to you in the form of **vehicle threat templates**. These templates are displayed on the map as shaded polygons that follow your UAV as it moves along its route. Every type of radar and Surface-to-Air Missile (SAM) has a template for your aircraft. Whenever a radar site is located inside the shaded polygon of its template, your UAV can be detected by that radar. When a SAM is inside of its template, you UAV could be shot down!

To understand how threat templates work and how they are created, think about shining a flashlight at a mirror: the amount of light that is reflected back to you depends on the power of your flashlight, the size of the mirror, and the direction it is facing. Radar signals work the same way. From a radar's point of view, an aircraft is made out of many mirrors all reflecting in different directions. The radar tries to see an aircraft by pointing a beam of radio waves at it and looking at what is reflected back. This means that the radar can only see the parts of the aircraft that reflect the beam straight back to it. The more signal that the aircraft reflects back to the radar, the farther away it can be seen. If an aircraft reflects very little signal, however, then it must be much closer to the radar to be detected. The amount of signal that an aircraft reflects back to a radar is called its **Radar Cross Section** (**RCS)**. The RCS of an aircraft is used in many real-world applications, including route planners, to estimate how close an aircraft can get to a radar before it will be detected.

As you might have guessed, the energy reflected from an aircraft will change depending on which angle the radar's beam comes from. For this reason, RCS data for an aircraft is often stored in an

Azimuth-Elevation, or **Az-El**, **table**. *Azimuth* is the horizontal angle relative to the nose of the aircraft – think of the nose as North, the right wing as East, the tail as South, and the left wing as West. *Elevation* in this case refers instead to the vertical angle – a signal arriving level with the aircraft has an elevation angle of 0 degrees, while one coming from directly underneath the aircraft has an elevation angle of -90 degrees. Together, azimuth and elevation angle create a system of coordinates which can refer to every angle that a radar beam might come from. Az-El data tables are created by analysts who measure the RCS of an aircraft from many azimuth and elevation angles inside a laboratory.

The capabilities of the radar itself must also be considered. The distance a radar can see depends on how powerful the radar is, and the angle between the ground and the radar's beam. These capabilities are often called **emitter characteristics**. A common way to store emitter characteristics is in something called a **Vertical Coverage Diagram** (**VCD)**. A VCD tells you how far away an aircraft can be seen by the radar, according to the aircraft's RCS and elevation.

The data in the Az-El table and the VCD can then be used to create vehicle threat templates. A computer places a virtual aircraft in the air in many different positions (such as straight, turning, climbing, or descending), and looks at it from hundreds of different locations on the ground. For each position of the aircraft and each location on the ground, the computer calculates the azimuth and elevation angles and uses them to look up the RCS in the Az-El table. This RCS and the vehicle's location are then looked up in the radar's VCD to figure out whether or not the aircraft would be detected at this location on the ground. Finally, the templates are formed by drawing outlines around all the locations from which a radar can detect the aircraft, and shading them in.

Vehicle threat templates are used in real-life route planners the same way that they are used in UAV Commander. Operators use

them to see whether an aircraft is vulnerable, and **autorouters** use them to create routes that are as safe as possible.

Integrated Air Defense System

The radars and missile sites of an air defense system do not operate independently. They cooperate through a communication network, in a collaborative effort to shoot down enemy aircraft. This system of radars, missile sites and the communication network between them is collectively called an **Integrated Air Defense System (IADS)**. An IADS can work in three steps, similar to how the different types of threats operate in UAV Commander. First, long-distance Early Warning radars scan a wide area searching for any aircraft. Once an enemy aircraft is detected, the EW radar alerts the entire IADS network to its presence and location. With this information, any tracking radars within range know exactly where to look to start tracking the aircraft. Once a tracker is locked on, it tells any missile shooters that are in range to fire.

Information about an enemy's IADS is very useful to route planners. For example, it might be safe for an aircraft to go within range of a tracking radar if no EW radars have detected it, or within range of a missile shooter if no trackers have locked on.

Autorouting

When playing UAV Commander, it is often necessary to create new routes for your UAVs whenever something unexpected happens. These routes are generated by an **autorouter**. An autorouter is a complex computer algorithm whose goal is to create good flight paths. This is a difficult problem: the routes it creates should avoid threats, accomplish tasks, stay clear of terrain, and stay within the flight capabilities of the aircraft. As you might imagine, this would be very difficult and time-consuming to do by hand.

Autorouters were originally used in pre-flight planning to figure out good routes well before the mission began. Since then, autorouters and computers have become much faster at creating

these routes. This has made *dynamic replanning* – fast generation of new routes while in-flight – possible. If autorouters were not capable of dynamic replanning, then controlling real UAVs would be nearly impossible. In fact, the autorouter in UAV Commander is based on real autorouting technology. Without it, it would not be so easy to change plans whenever something pops up!

Levels of Autonomy

An autorouter capable of performing dynamic replanning is not the only obstacle to overcome in the development of UAV technology. Modern versions of real-flight UAVs require a large team of people to control just one aircraft. Compare this to UAV Commander, where just one player can control several UAVs at once! The ratio of the number of UAVs controlled to the number of operators controlling them is called the *span of control*. If more UAVs can be controlled with fewer operators, then the span of control is larger; if it takes more people to control fewer UAVs, then the span of control is smaller.

Increasing span of control is currently an active area of UAV research. UAV Commander is actually derived from some of this research, where the span of control is increased using what are called **levels of autonomy**. During a mission, the UAV operator must be kept alert and in control. When not much is happening, there must be enough to do so that the operator does not get bored or stop paying attention. When many things happen at once, however, the operator must not be overwhelmed with decisions to make or tasks to do! To solve this problem, the computer will vary the level of autonomy. When not much is going on, the level of autonomy is reduced – meaning that not very many things will be done automatically. Instead the operator will be given small tasks and will be asked questions about the situation to maintain alertness. Then, when threats start popping up or a more complex part of the mission begins, the level of autonomy is increased – the computer will do more things automatically, leaving only the more important tasks and decisions up to the operator. This way the operator will not be overwhelmed by having too much to do.

About the Developer

OR Concepts Applied (ORCA) is a technical services and software development firm that applies Operations Research concepts to real and projected problems. ORCA's specialty is military vehicle route planning and analysis. While many ORCA projects are related to military mission planning, ORCA works on a variety of problems including internet grocery delivery planning and web-based tools to enhance aircraft maintenance operations.

ORCA is best known for the ORCA Planning and Utility System (OPUS), which is a military aircraft mission planning and analysis COTS software. OPUS has been in development since 1991. It was first licensed by the USAF in 1993. Recently, OPUS technology enabled two X-45A unmanned aircraft to successfully complete graduation exercises that required autonomous vehicles to cooperate. OPUS dynamically and autonomously replanned the vehicles' missions while the vehicles were in flight.

Below are a few of the significant endorsements and milestones for OPUS technology:

- Certified for operational use by the U.S. Air Force
- Used by the USAF-Europe during the Air War over Serbia
- Endorsed by the Navy's UAV Advanced Technology Review Board
- OPUS technology is used in various UAV programs

The OPUS component-based architecture allows OPUS mission planning services to be accessed by other applications. ORCA and third party developers have embedded OPUS technology in other products, including several unmanned vehicle applications. ORCA's Adaptive Levels of Autonomy (ALOA) product – on which the UAV Commander game is based – includes a mission control element (MCE) for managing multiple UAVs simultaneously that makes use of OPUS technology. ORCA's Multi-Vehicle Mission Planner (MVMP) product extends OPUS and ALOA capabilities to unmanned sea and undersea vehicles.