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Virtual ISR Evaluation Environment (VIEE++) training package

Nathan Kashyap
Daniel Brookes
Dr. Rahim Jassemi-Zargani
DRDC – Ottawa Research Centre

Prepared For:
1 Canadian Air Division Headquarters, Winnipeg, MB R3J 3Y7

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IMPORTANT INFORMATIVE STATEMENTS

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Abstract

This Defence Research and Development Canada (DRDC) – Ottawa Research Centre Reference Document is a training manual that was used in training operators, officers, and planners at 1 Canadian Air Division (1 CAD) in Winnipeg in March 2018. The training was based on a software called Virtual Intelligence, Surveillance and Renaissance (ISR) Evaluation Environment (VIEE++) which is a custom licensed version of Trackgen Solutions Inc. ISR360 product. VIEE++ is an ISR evaluation environment that allows for multi-sensor multi-domain scenario generation and analysis of surface, sub-surface, air, land and space targets/platforms. Radar measurement generation, tracking and data fusion are modelled in this unified framework. The purpose of the training session was to present how DRDC – Ottawa Research Centre uses VIEE++ and how it could be applied to 1 CAD operational mission planning. Given time constraints, not all features of the application were presented during the training session.

Significance to Defence and Security

VIEE++ has the ability to help 1 CAD and other military domains as a decision making tool for operational mission planning analysis. With an ISR catalog, line-of-sight coverage analysis, detection, measurement, tracking and data fusion generation and analysis, these are some of the tools available in the users toolbox.

Résumé

Le présent document de référence, élaboré par le Centre de recherches d'Ottawa de RDDC, est un manuel de formation ayant servi à l'apprentissage des opérateurs, des officiers et des planificateurs de la 1ère Division aérienne du Canada (1 DAC) à Winnipeg en mars 2018. La formation portait sur un logiciel appelé Virtual ISR Evaluation Environment (VIEE++), une version personnalisée du produit ISR360 de Trackgen Solutions Inc. sous licence d'exploitation. VIEE++ fournit un environnement pour l'évaluation du renseignement, de la surveillance et de la reconnaissance (RSR). Plus précisément, il permet de générer des scénarios multicapteurs et multidomaines, et d'analyser les plateformes ou les cibles de surface, sous-marines, aériennes, terrestres ou spatiales. La génération de mesures de signaux radar, la localisation et la fusion de données sont modélisées dans ce cadre unifié. Le but de la séance de formation était d'expliquer comment le Centre de recherches d'Ottawa utilise VIEE++ et d'énumérer les possibilités d'application par la 1ère Division aérienne du Canada dans la planification des missions opérationnelles. Vu les contraintes de temps, les caractéristiques du logiciel n'ont pas toutes été abordées pendant la séance de formation.

Importance pour la défense et la sécurité

Comme outil d'aide à la prise de décisions, VIEE++ pourrait aider la 1ère Division aérienne du Canada et d'autres secteurs au sein des Forces armées à analyser la planification de leurs missions opérationnelles. La trousse d'outils de l'utilisateur comporte notamment un catalogue RSR, ainsi que des outils d'analyse de la couverture en visibilité, de détection, de mesure, de localisation, ainsi que de génération et d'analyse de la fusion de données.

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1 Introduction

VIEE++ is an integrated plug-in capable service-oriented software toolset for analysis and visualization of ISR systems. It offers a widespread ISR analysis solution for air, space, ground, maritime and underwater scenarios.

VIEE++ allows you to specify and analyze multisensor-multitarget ISR problems with varying levels of fidelity. Surveillance platforms with radar, sonar, Moving Target Indicator (MTI), video, EO/IR, GPS, AIS/ADS-B, or multistatic sensors are modelled within a unified framework to provide versatile ISR capability.

Key features [1]:

- Scenario generation;
- Heterogeneous sensor modelling;
- Diverse ISR system specification;
- Optimal resource scheduling & management;
- High performance tracking and fusion;
- Recognition, identification and classification;
- Common ISR picture;
- Informative visualization;
- In-depth sensor, track and data analysis;
- Comprehensive performance evaluation;
- Extensible with plug-ins and services;
- Rapid prototyping with user-defined modules;
- Real-time capable scenarios.

Protocols and formats [1]:

- Data from network, files, databases and plug-ins;
- Transfer messages and data through Data Distribution Service (DDS);
- Data in ASTERIX (CAT 21,34,48,62), CD2 and ASR9;
- Support for other protocols and formats via plug-ins.

Integrated modules [1]:

- SceneGen: multisensor-multitarget ISR scenario generation and simulation;
- ISR-Mgr: optimal resource and task manager for surveillance or decision support systems;

- MultiTrack: high performance multitarget tracking with IMM-based MHT, MFA, JPDA, and JIPDA, (see Terminology list below) trackers;
- MultiFuse: centralized and distributed multisensor data fusion for heterogeneous systems;
- ISR-Analytics: in-depth data analysis for situation awareness and recognition & identification;
- ISR-MoP: ISR system performance evaluation and comparison.

System requirements:

Recommended system configuration includes:

- Windows 7, Windows 8 or Windows 10;
- 32GB of RAM;
- 5GB of free disk space;
- 1366x768 screen resolution or higher;
- A graphics card that support OpenGL 3.0 (or higher) with at least 256 MB memory.

Terminology:

AOI	Area of interest
Detection	Same as measurement
Estimate	Calculated state of a target
Frame	Same as radar sampling time, the minimum time possible between consecutive measurements from same target. For a rotating radar, one rotation is the frame time.
Fusion	Fusion of measurements or/and tracks from multiple sources
Ground truth	Actual target state
IMM	Interacting Multiple Model
JIPDA	Joint Integrated Probabilistic Data Association
JPDA	Joint Probabilistic Data Association
Measurement	Thresholded detection, which is a noise-corrupted observation related to the state of a target
MFA	Multi-Frame Association
MOP	Measure of performance
NWS	North Warning System
PE	Performance evaluation, which is same as MOP
Pd	Probability of detection
Platform	A vehicle (e.g., satellite, aircraft, ship, car) or a surface used to carry sensors

Plot	Graphics (does not mean detection)
Raw data	Received signal without applying any thresholding
Sensor	A device that detects targets
State	Position, velocity and any other kinematic parameters of a target at a certain time
Target	Same as Ground truth
Track	Estimated trajectory of a target
Truth	Same as Ground truth

Symbology for training manual:


Information icon


Warning


Questions to be answered by student


Student exercise


Hint

2 VIEE++ Training Overview

Table 1: *VIEE++ training schedule.*

Tutorial	Description
DAY 1	
Quick Start	Instructor will demonstrate a pre-loaded scenario.
PART 1: Launch VIEE++	Learn how to run VIEE++.
PART 2: User interface	Getting familiar with the user interface.
PART 3: GUI (Graphical User Interface) builder	Learn the controls of the GUI to build a scenario in VIEE++.
PART 4: Detection and Tracking *Project No. 1 "Single ground based radar"*	Learn how to build and execute a scenario in VIEE++ with the GUI, based on a single ground based radar. **HANDS on exercise: Project No. 1**
BREAK	
PART 5: Multi-mode Detection and Tracking *Project No. 2 "Single short and long range ground based radar"*	Learn how to build and execute a scenario in VIEE++ with the GUI based on a short and long range ground based radar. **HANDS on exercise: Project No. 2**
LUNCH	
PART 6: Multi-sensor Data Fusion *Project No. 3 "Merging two ground based radars"*	Learn how to build and execute a scenario in VIEE++ with the GUI based on a Multi-function Phased Array Radar (MPAR) and North Warning System (NWS) ground based radar. **HANDS on exercise: Project No. 3**
DAY 2	
PART 7: Beam Pattern Emulation *Project No. 4 "NAV Canada RAMP radar"* *Project No. 5 "AESA radar"*	Learn how to build a complex radar (RAMP and AESA) with multiple beams within VIEE++.

Tutorial	Description
PART 8: Complex multi-sensor multi domain scenario	The focus up until now has been ground based radar detection of air targets. This scenario will bring in satellite, aircraft platforms and ship targets.
PART 9: Coverage/Detection plots	This section will explore the coverage/detection plotting capability in VIEE++ which helps visualize sensor performance.
PART 10: Other Features	Learn how to use additional features: • Monte Carlo • Saving the plot • Export data • Display DTED map
LUNCH	
PART 11: Work through custom scenarios	Students have the opportunity to work through scenarios of interest with the help of trainers.
DAY 3	
PART 11: Continued from previous day	
PART 12: Q&A Session	

2.1 Quick Start

The instructor will launch and describe the following VIEE++ actions to quickly get the students familiar with the application:

- Launching the application
- Opening a project
- Editing a project
- Running a project
- Analyzing results
- Closing a project
- Exiting the application

2.2 Part 1: Launch VIEE++

1. **Launching VIEE++ for the first time**

To launch the VIEE++ application, look on your desktop for the VIEE++_1CAD icon 

and use your mouse to double-click it.

The VIEE++ logo should appear and then the VIEE++ application with open. By default, the most recent project that was last saved will be the project that is opened on your screen.

If you zoom out, your screen should now look similar to Figure 1.

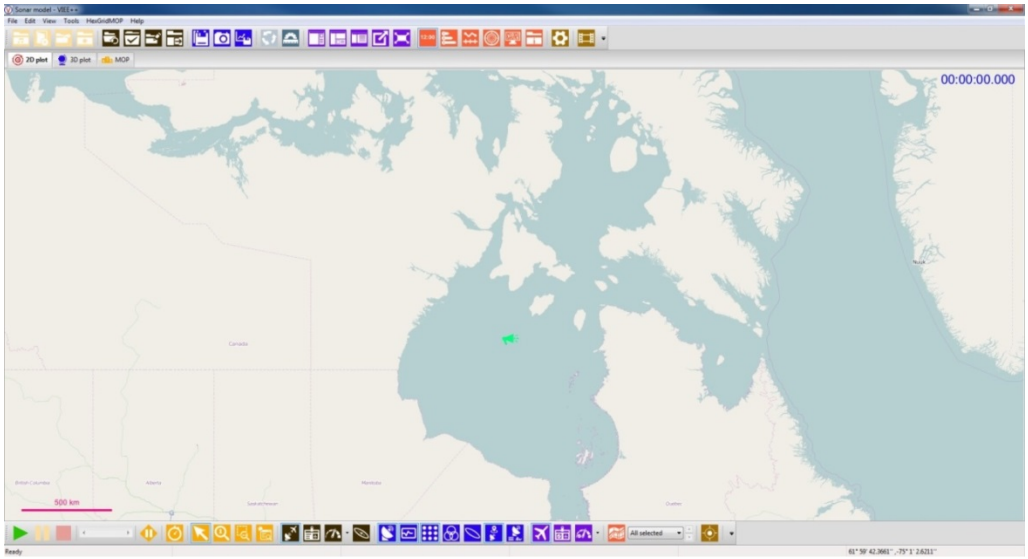


Figure 1: Screenshot of VIEE++ application. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)

2. **Open an existing project**

Open a different project by selecting **File | Close project.** Click **Yes** in the dialog that pops up to close the project click **File | Open project**. This will open the "Please select a project file" dialog box. Project files are typically stored in C:\ISR360_VIEE++_v20180202\misc\ directory. For the training, all scenarios will be stored in the ..\misc\Training folder. The format of a VIEE project file has the .360 extension. The contents of this xml file store all the configuration parameters for the main project. The majority of the changes to this file can be done through the GUI which will be described later in the training session. You will notice there are associated directories with the same name as the .360 project files. This is where the project related configuration details are stored.

For example, the NWS_MPAR_Ground_Based_Radar.360 project has an associated project folder called "NWS_MPAR_Ground_Based_Radar." If you open the

C:\ISR360_VIEE++_v20180202\misc\Training\Exercise_solutions\NWS_MPAR_Ground_Based_Radar\ External directory, the following project related sub-directories will appear:

fuser	→	Stores the fusion object parameters
mop	→	Stores the measures of performance configuration
sensor	→	Stores sensor configuration parameters, for example if you had a 3D radar in your simulation this is the directory which stores all parameters related to that specific radar.
tracker	→	Stores all tracking parameter files. For example, if you create a sensor in a scenario that you want to build tracks for instead of just detections, this is the directory which stores all tracking configurations.
truth	→	All truth target information is stored in this directory. For example, if you have a ship and an aircraft in your scenario as truth targets they would be stored here.

Note that each scenario directory will be created based on what has been created in the GUI designer and may have more, equal or less number of directories shown above.

Browse to the training directory under C:\ISR360_VIEE++_v20180202\misc\Training\Exercise_solutions and select the "NWS_MPAR_Ground_Based_Radar.360" project and click Open. Your VIEE++ screen should look like Figure 2 once you click on the "sensor coverage icon"  on the control panel.

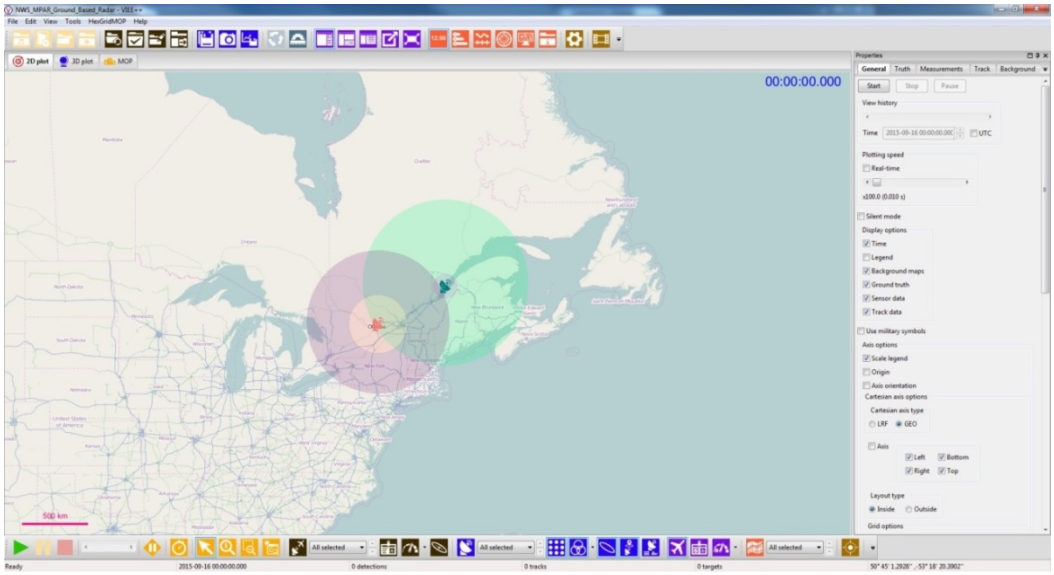


Figure 2: VIEE++ 2D map display after opening an existing project. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)

2.3 Part 2: User interface

Continuing from Part 1, enable the following toolbars and panels from the Menu bar:

1. Click **View | Property panel**
2. Click **View | Status panel**
3. Click **View | Summary panel**
4. Click **View | Toolbar | Playback**

Your VIEE++ user interface should now look like Figure 3.

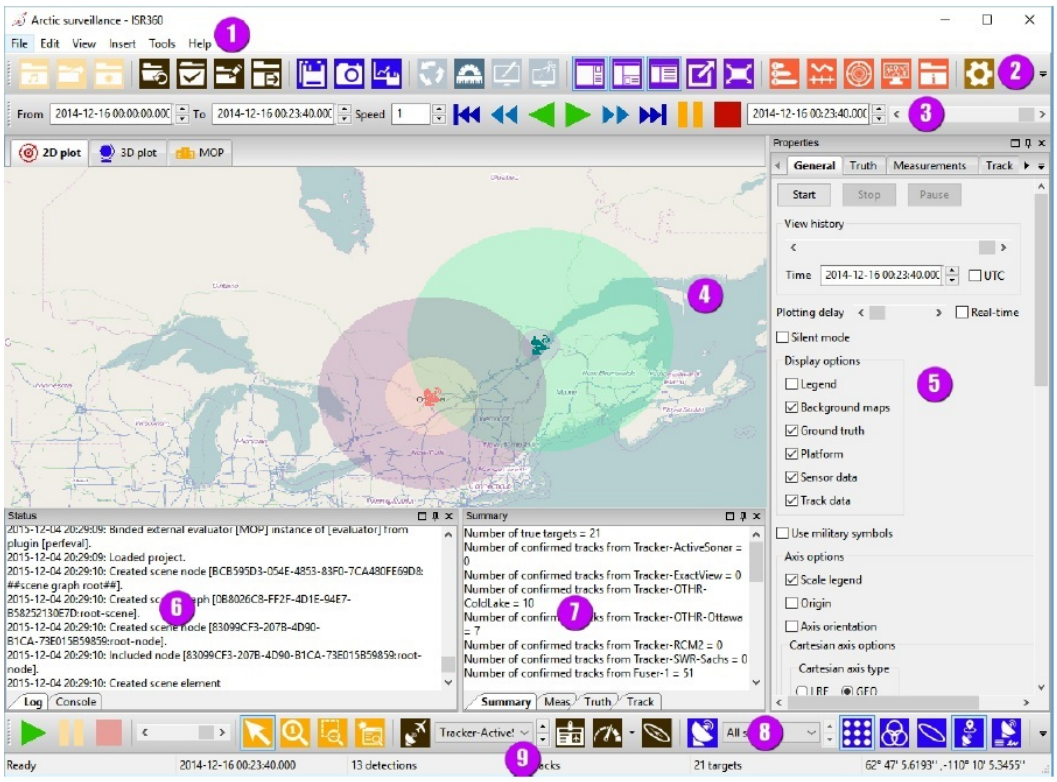


Figure 3: *VIEE++ user interface. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

1. Menu
2. Main toolbar
3. Playback toolbar
4. Plot panel
5. Properties panel
6. Status panel

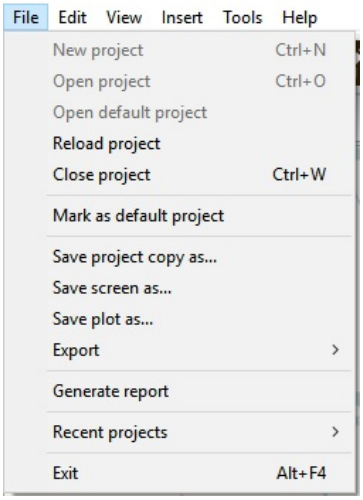
7. Summary panel
8. Control panel
9. Status bar

1. **Menu**

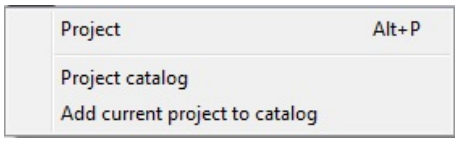
On the top of the VIEE++ application, you will see the menu bar with the following menus:

- File menu
- Edit Menu
- View menu
- Tools menu
- HexGridMOP (not required)
- Help

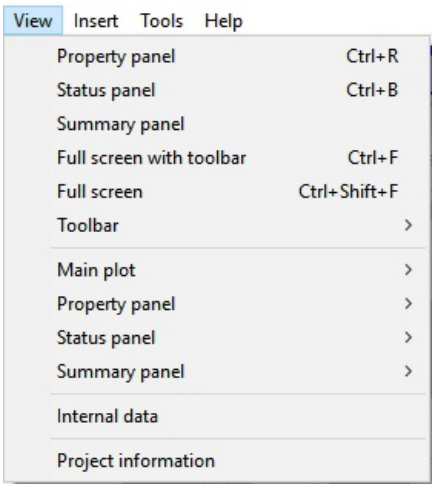
Under **File menu**, there are a number of sub items to choose from.



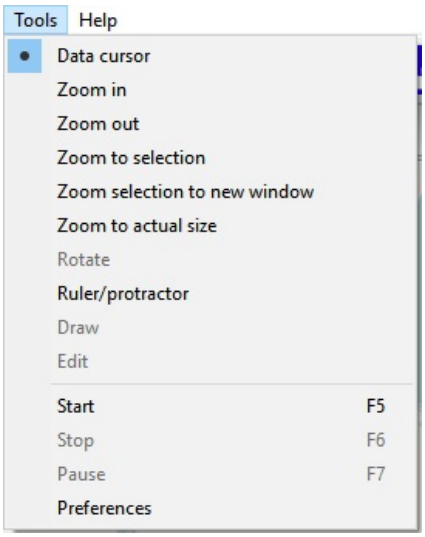
Under **Edit menu**, you can edit your existing project using the GUI.



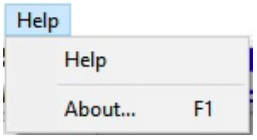
Under **View menu**, you can toggle a number of panels to the display.



Under **Tools menu**, you can change many display options.



Under **Help menu**, you can view the "Help" documentation.



2. **Main toolbar**

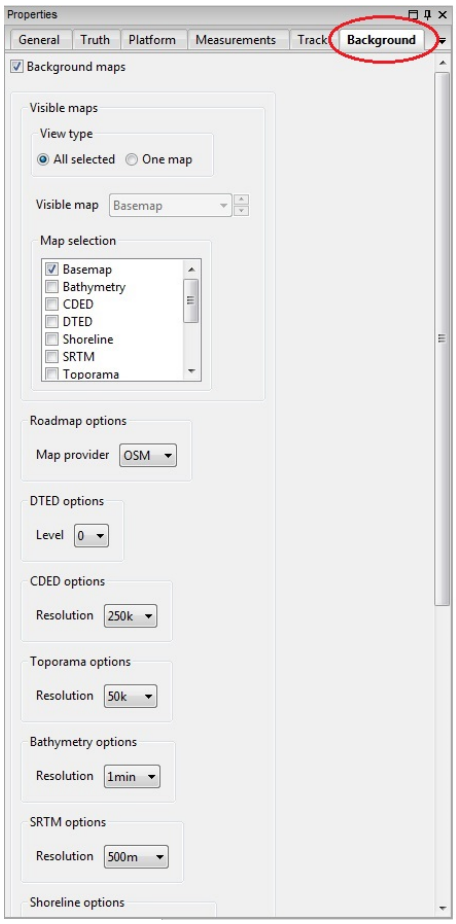
When no project is opened:

When a project is opened:

The items on the main toolbar, in order from left to right, are described below:

5. **Properties panel**

By default the Properties panel is hidden. To bring it up on the display, click **View | Property panel** from the menu. The "Background" tab of this panel is shown in the figure below.

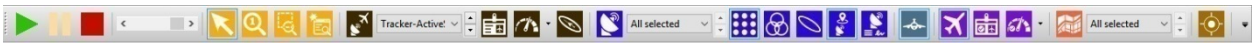


There are six tabs under the Properties panel:

General	→	You can run your scenario and change general scenario display properties here.
Truth	→	Display properties for the ground truth included in your scenario.
Platform	→	Display properties for the platforms (e.g., aircraft, ship, satellite) included in you scenario.
Measurements	→	Display properties for the measurements generated from the sensors included in the scenario.
Track	→	Display properties for the tracks generated from the measurements generated from the sensors included in the scenario.
Background	→	Display properties for changing the background of the map display.

8. **Control panel**

The Control panel is typically shown on the bottom of the VIEE++ application window:



This control panel contains a subset of the tool (from the Properties panel) an operator would use the majority of the time.

The items on the Control panel are described below:

2.4 Part 3: GUI Builder

Continuing from Part 2, we will first look at editing an existing scenario. Remove the following toolbar and panels from the display:

1. Click **View | Status panel**

2. Click **View | Summary panel**

3. Click **View | Toolbar | Playback**

4. Click **Edit | Project** from the Menu bar. The main designer window will appear. Click the Collapse all icon. Your GUI should look similar to Figure 4.

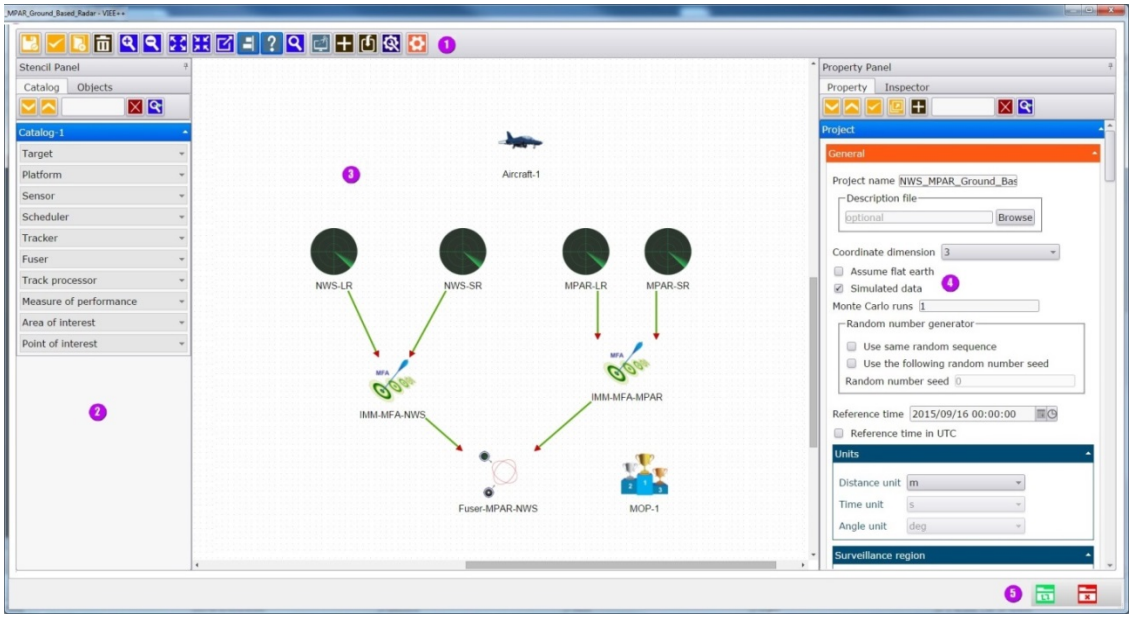


Figure 4: *VIEE++ GUI builder. (Used with permission from Trackgen Solutions Inc.)*

1. Top toolbar
2. Catalog panel
3. Canvas
4. Property panel
5. Bottom toolbar

The Catalog panel has the following objects to drag onto the Canvas:

- Target
- Platform
- Sensor

- Scheduler (N/A for this training)
- Tracker
- Fuser
- Track processor (N/A for this training)
- Measure of performance
- Area of interest
- Point of interest (N/A for this training)

Instructor: To show how to drag and drop objects onto the Canvas from the Catalog panel.

Now, it is time to create your own scenario. Click the Close project icon  at the bottom right of the designer window.

Click **Yes** to ignore saving any changes to the scenario.

Click **File | Close project**. Click **Yes** to close the project.

2.5 Part 4: Detection and Tracking

2.5.1 Project No. 1—Single Ground Based Radar

This section will use the VIEE++ GUI Builder to create a simple scenario with a single aircraft target passing through a single ground based radar sensor. See Figure 5 for an example of Project No. 1.

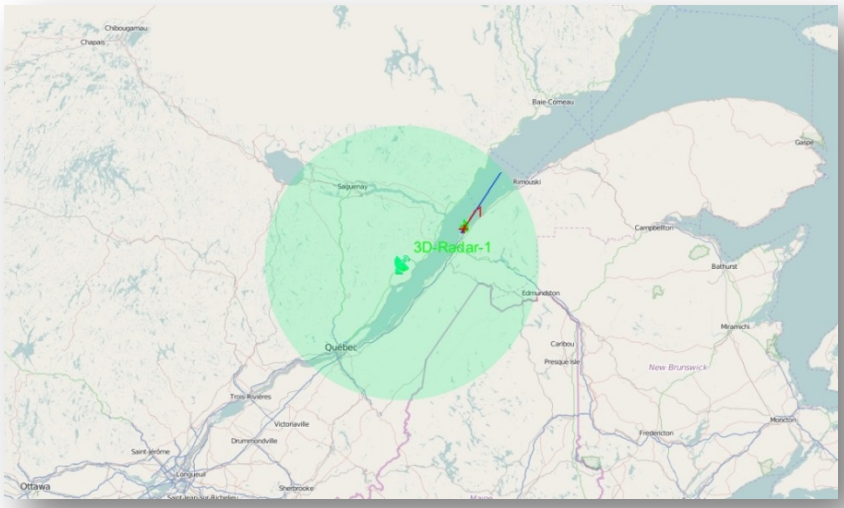


Figure 5: *VIEE++ 2D map window display of Project No. 1—Single ground based radar. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

NOTE: Students will follow along with the trainer to create a scenario in VIEE++.

1. Click **File | New project** from the main menu.

   A *Create project* file dialog will pop up. Within the *VIEE++ folder C:\ISR360_VIEE++_v20180202\misc\Training\Student_exercises* folder type "Single_Ground_Based_Radar" as the project *File name*. Click **Save**.

2. The GUI Builder window appears requesting the user to "Select a Template." Click the **Blank** template.

3. Setting Properties for your scenario:

   a. The Project properties are displayed where the user will fill in general parameters about the overall scenario.

   b. In the "Project name" field type "Single_Ground_Based_Radar."

c. Scroll down to the Surveillance region section and click on the  icon to select a map region. In the "Pick on map" window, move the place marks so that the surveillance region looks similar to Figure 6. Click OK to confirm.

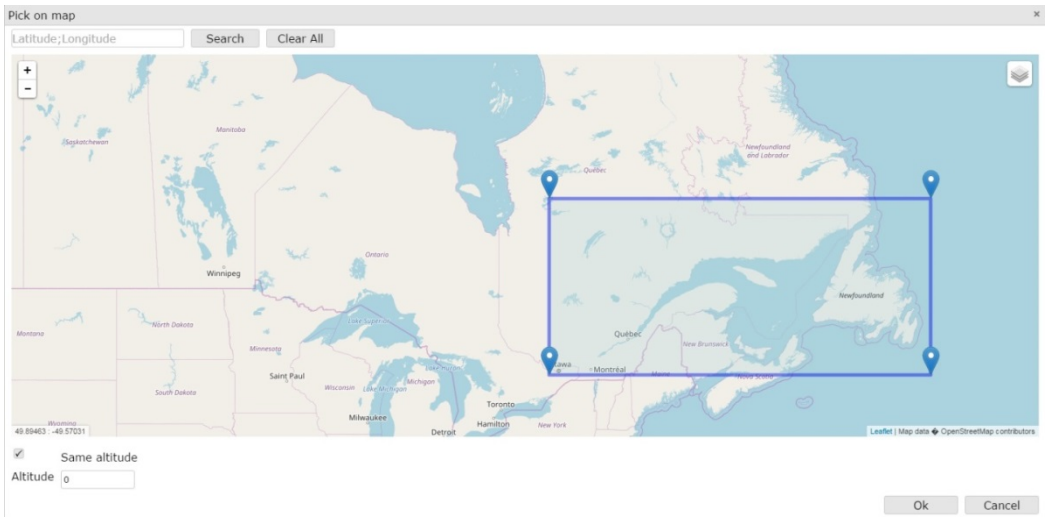


Figure 6: *Project No. 1 "Pick on Map" surveillance region.*
(Used with permission from Trackgen Solutions Inc.)

d. Under the Duration section, deselect "Auto step duration" and enter 3 as the "Duration" since the sensor that we will add to the scenario in the following steps will have a sampling rate of 3 seconds.

e. Click the  arrow at the top right of the window to move on to the GUI Builder to create objects for your scenario.

4. Selecting a Target:

a. Drag and drop the Aircraft icon onto the Canvas.

b. From the Property panel, edit the properties of your target:

i. In the General section, set the Target ID to 200.

ii. In the Trajectory section, click the  pick on a map icon to select the trajectory for your aircraft. Select a trajectory similar to Figure 7.

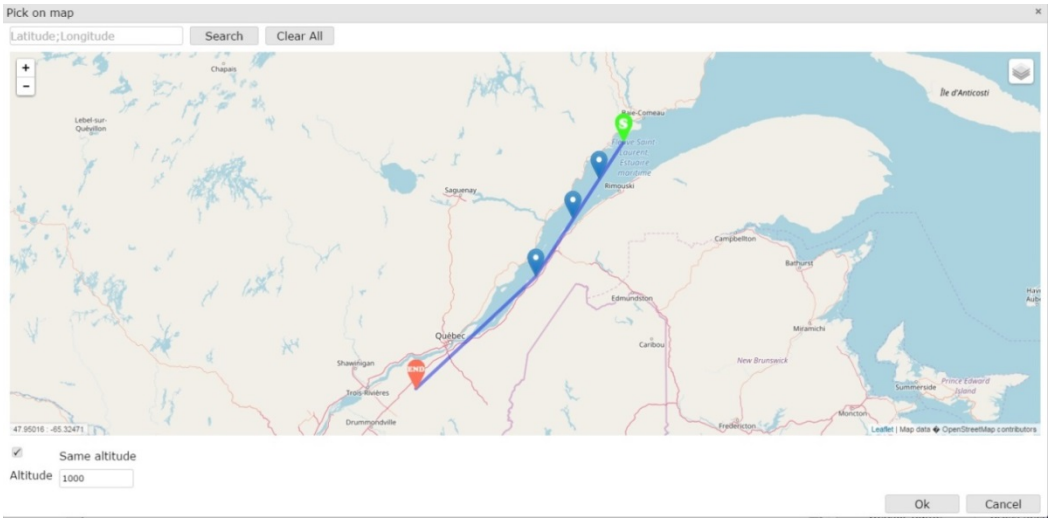
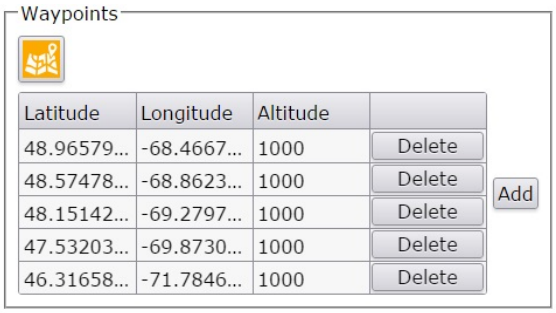


Figure 7: *Project No. 1 "Pick on Map" waypoints for aircraft target. (Used with permission from Trackgen Solutions Inc.)*

iii. Set the Altitude to 1000. This will assign an altitude of 1000 m to each of the waypoints.

iv. Click **OK**.

v. For your reference, the waypoints in the figure above are shown in Figure 8, which can be found in the Trajectory section within the Properties panel.



Latitude	Longitude	Altitude	
48.96579...	-68.4667...	1000	Delete
48.57478...	-68.8623...	1000	Delete
48.15142...	-69.2797...	1000	Delete
47.53203...	-69.8730...	1000	Delete
46.31658...	-71.7846...	1000	Delete

Figure 8: *Project No. 1 Waypoints window. (Used with permission from Trackgen Solutions Inc.)*

5. Selecting a Sensor:

   a. From the Catalog Panel, drag and drop the "2D-Radar" sensor onto the Canvas.

   b. Edit the properties of your Radar.

      i. In the General section, change the following:

         - Change the Name to "3D-Radar-1."
         - Change the Type to "3D_Radar."

- Set the Sampling time to “3.”

ii. In the Position section, change the following:

- Set the Altitude mode to “RelativeToGround.”
- Set the Latitude to 47.647.
- Set the Longitude to -70.173.
- Set the Altitude to 50.

iii. In the Measurements section, change the following:

Range:

- Set the Minimum Range to 150.
- Set the Maximum Range to 150000.
- Set the Error standard deviation for Range to 150.

Bearing:

- Leave the Minimum and Maximum Bearing at -180 and 180 respectively.
- Set the Error standard deviation for Bearing to 1.

Elevation:

- Set the Minimum Elevation to -5.
- Set the Maximum Elevation to 20.
- Set the Error standard deviation for Elevation to 1.

iv. In the Additional coverage variables section, change the following:

- Select the “Check line-of-sight” checkbox.
- Select the “Use terrain for LOS calculation.”

v. In the Detection section, change the following:

- De-select Constant PD (Probability of Detection).
- For Nominal range SNR, set the Range0 to 150000, Sigma0 to 1 and SNR0 to 12.

6. Setting the target RCS:

a. Click on the aircraft target and scroll down the properties to the Mean cross sections section.

b. Click **Add row**.

c. For the Sensor name, enter the name of the sensor you added in the previous step, for example “3D-Radar-1” and enter the Cross section as 1. Note, by default, if the cross section is not specified, the target RCS with respect to any sensor is $1m^2$.

7. Selecting a Tracker:

The tracker will be used to build tracks from the measurements generated from the sensor object. The tracking object has four trackers to choose from: mfa, jpda, jipda and mht. Setting tracking parameters is quite complicated and should be done with the aid of a tracking expert. For this training, we will use the default mfa tracker and leave all the parameters as is.

a. In the Catalog panel under Tracker, drag and drop the “IMM-MFA” tracker onto the Canvas.

b. Click the 3D-Radar-1 sensor created in Step 5, and click and drag the arrow to connect the sensor to the Tracker object.

c. Leave the parameters for the Tracker object as is.

8. Adding Measures of Performance (MOP):

Over 30 MOPs can be added to your scenario. These measures can be used to measure the performance of the systems in your scenario. For example, the Tracklife MOP will provide the time in seconds of how long the target has been tracked in the scenario. The definition of all the metrics that could be used in VIEE++ are listed in Annex A at the end of the training package.

a. In the Catalog panel under Measure of performance, drag and drop the MOP image onto the Canvas.

b. In the Property panel for MOP-1 set the Maximum position error to 25000.

c. We will leave all other MOP values as default.

Your Canvas should look something similar to Figure 9.

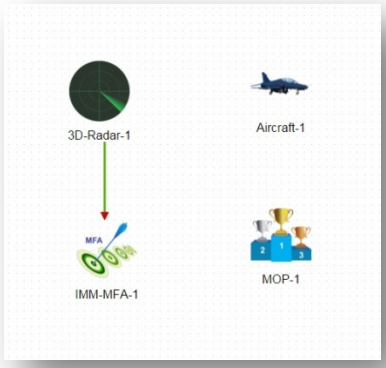


Figure 9: *Project No. 1 VIEE++ GUI Builder canvas.*
(Used with permission from Trackgen Solutions Inc.)

9. Save the project:

   Saving the project for the first time will create the project file and directories (sensor, target, truth, ...) related to the scenario. If you cancel out of the GUI Builder window all changes will be lost.

   Click the  Save project icon at the bottom right of the window.

10. Running your project:

    Your map window should now look similar to Figure 10.

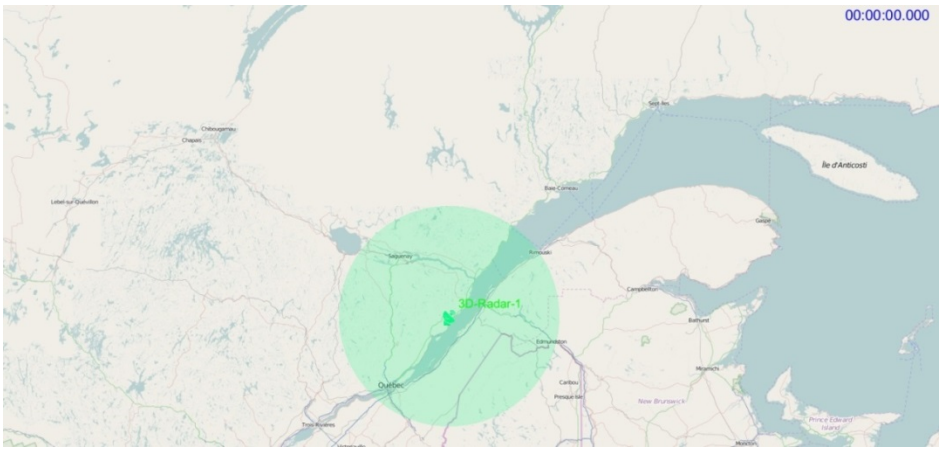


Figure 10: *Project No. 1 VIEE++ map display of radar field of view. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

a. Click **View | Property panel**.

b. From the Property panel General tab, set the Plotting speed to x75.0 by clicking the right slider arrow.

c. Click Start. The aircraft target should appear after you click the button.

d. When the aircraft enters the radar coverage area and the red track appears, click Pause.

The aircraft target ground truth is represented by the Blue line with the aircraft at the tip. The false alarms and measurement data are represented by the green circles. The aircraft track generated by the measurement data is represented by the red line with a "+" at the tip. Figure 11 shows a snapshot of the scenario with these markings.

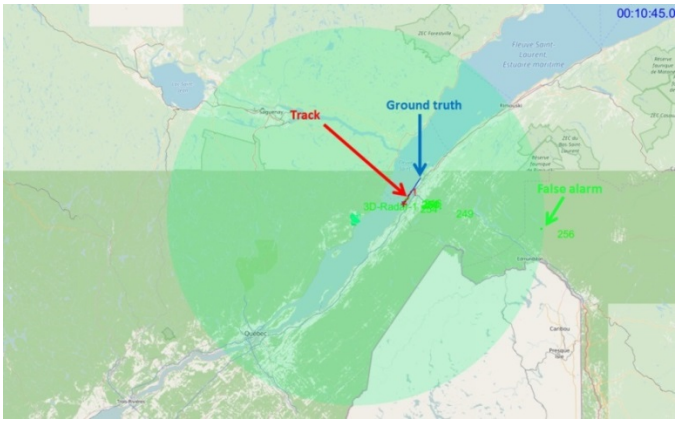


Figure 11: *Project No. 1 VIEE++ map display with ground truth (blue), predicted track (red) and radar measurements (green). (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

You can extend the length of the track or ground truth target in the Property panel, however since this is tied to memory consumption this may slow down your system considerably.

e. Click Resume. When the red track disappears click Pause.

11. Accessing the metrics:

a. Click the MOP tab 

at the top of the map plot panel.

b. The instructor will briefly review some of the metrics for this scenario.

1. **Approximately, how far from the radar (centre) is the target first detected?**

   _____

2. **Approximately, how far from the radar (centre) is the target first tracked?**

   _____

3. **What happens when you change the altitude of the target to 15000 m?**

   _____

4. **Change the RCS of the target to 0.01m^2, making it a much smaller target to detect/track. Does the target still get tracked?**

   _____

2.6 Part 5: Multi-mode Detection and Tracking

2.6.1 Project No. 2—Single Short and Long Ground Based Radars

This section will build upon the concepts we have learned from Part 4 and create a scenario that combines the measurements from two radars into one. See Figure 12 for an example of Project No. 2.

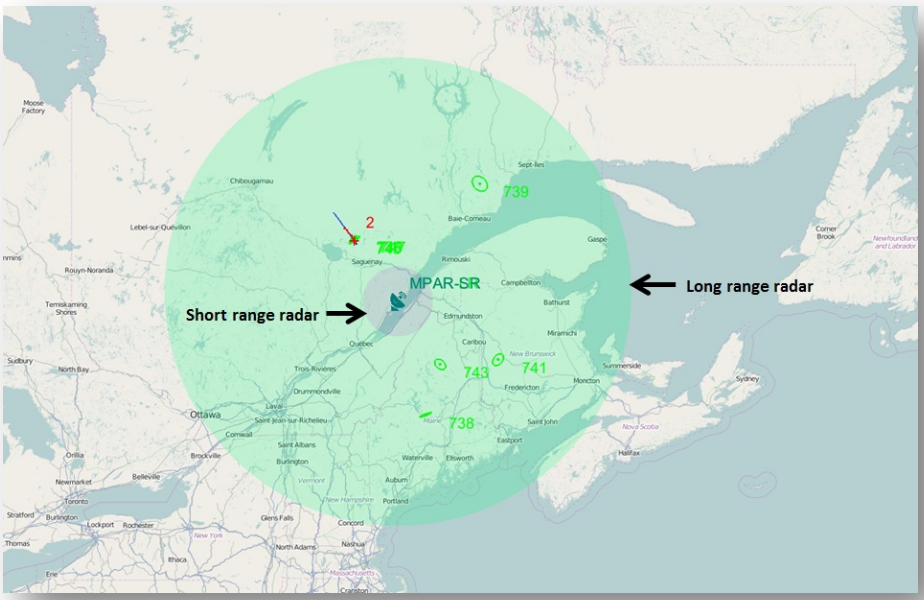


Figure 12: *VIEE++ 2D map display of Project No. 2—Single short and long range ground based radar. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

1. Click **File | Close project**. Click Yes to close the project.

2. Click **File | New project** from the main menu.

3. A Create project file dialog will pop up. Within the VIEE++ folder C:\ISR360_VIEE++_v20180202\misc\Training\Student_exercises folder enter "MPAR_Ground_Based_Radar" as the project File name. Click Save.

4. The GUI Builder window appears requesting the user to "Select a Template." Click the Blank template.

5. Setting Properties for your scenario:

   a. The Project properties is displayed where the user will fill in general parameters about the overall scenario.

b. In the “Project name” field set the project name to “MPAR_Ground_Based_Radar.”

c. Scroll down to the Surveillance region section and click on the  pick on a map icon. In the “Pick on map” window, move the place marks so that the surveillance region looks similar to Figure 13. Click Ok.

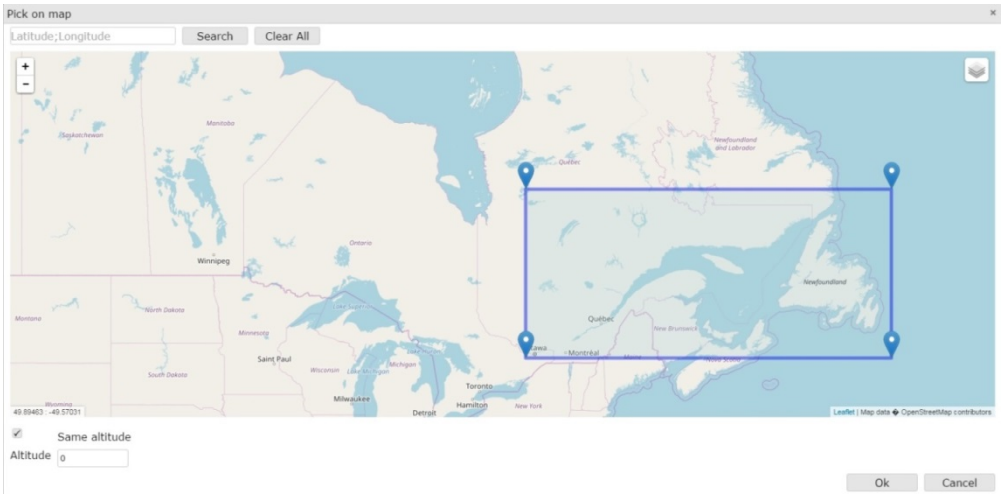


Figure 13: *Project No. 2 “Pick on map” window. (Used with permission from Trackgen Solutions Inc.)*

d. Click the  arrow at the top right of the window to move on to the GUI Builder to create objects for your scenario.

 Based on the figure and information provided below, create the scenario and answer the corresponding questions.

When you are finished creating your scenario, your Canvas should look similar to Figure 14. You need to add one air target, two sensors and one IMM-MFA tracker. The parameters for these objects are below.

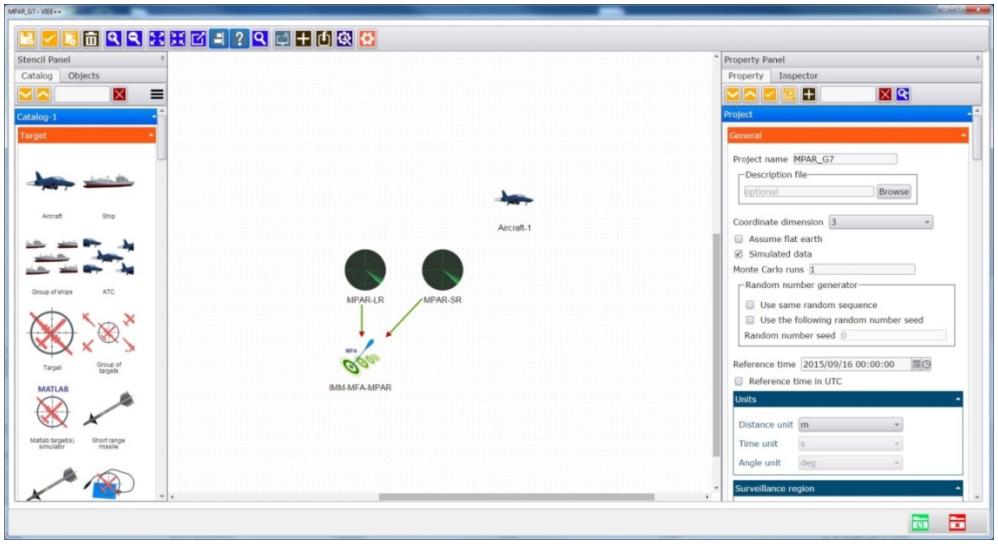


Figure 14: *Project No. 2 GUI builder window. (Used with permission from Trackgen Solutions Inc.)*

1. Target aircraft parameters:
   - Target ID = 200
   - Trajectory
     - Latitude = 51.0966, Longitude = -74.1137
     - Latitude = 47.62968, Longitude = -70.1648
     - Altitude (constant) = 10000

2. Sensor parameters (long range MPAR-LR):
   - Name = MPAR-LR
   - Category = Monostatic_Active
   - Type = 3D_Radar
   - Sampling time = 3
   - Position
     - Altitude mode = relativeToGround
     - Latitude = 47.62958
     - Longitude = -70.16487
   - Measurements
     - Range
       - Minimum = 75000
       - Maximum = 500000

        - Error standard deviation = 150
    - Bearing
        - Minimum = -180
        - Maximum = 180
        - Error standard deviation = 1.5
    - Elevation
        - Minimum = -5
        - Maximum = 60
        - Error standard deviation = 1.5
- Additional coverage variables
    - Select “Check line-of-sight”
    - Select “Use terrain for LOS calculation”
- Detection
    - Disable Constant PD
    - Nominal range SNR
        - Range0 = 470000
        - Sigma0 = 1
        - SNR0 = 12

For the second sensor you can use the clone object on the Canvas as shown below.

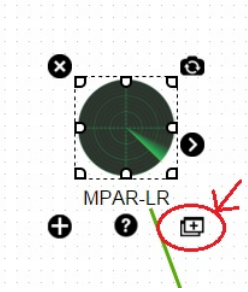


Figure 15: *How to clone a sensor in VIEE++. (Used with permission from Trackgen Solutions Inc.)*

3. Sensor parameters (short range MPAR-SR):

- Name = MPAR-SR
- Category = Monostatic_Active
- Type = 3D_Radar

- Position
  - Altitude mode = relativeToGround
  - Latitude = 47.62958
  - Longitude = -70.16487
- Measurements
  - Range
    - Minimum = 150
    - Maximum = 75000
    - Error standard deviation = 150
  - Bearing
    - Minimum = -180
    - Maximum = 180
    - Error standard deviation = 1.5
  - Elevation
    - Minimum = -5
    - Maximum = 60
    - Error standard deviation = 1.5
- Additional coverage variables
  - Select “Check line-of-sight”
  - Select “Use terrain for LOS calculation”
- Detection
  - Disable Constant PD
  - Nominal range SNR
    - Range0 = 125000
    - Sigma0 = 1
    - SNR0 = 12

4. Tracker:

   a. Add IMM-MFA tracker to the Canvas.

   b. Change the name of the tracker to “IMM-MFA-MPAR.”

   c. Connect the measurements from the two short and long range radars to a mfa tracker.

5. Metrics: Add default metrics to the scenario.

a. Set the “Maximum position error” for the Truth-Track association to 25000.

6. Save the project.

1. Approximately, how far from the radar (centre) is the target first tracked?

_____

2. What are the following metrics after the radar stops tracking the target?
Tracklife = _____
TrackPD_FOV = _____
SensorPD_FOV = _____

3. What happens to the Tracklife of the target when you change the altitude of the target to 5000 m?

_____

2.7 Part 6: Multi-Sensor Data Fusion

2.7.1 Project No. 3—Merging Two Ground Based Radars

This section will build upon what we have learned from Part 5 and create a scenario that combines the measurements/tracks from two different radars and fuse them into one.

1. Click **File | Close project**. Click Yes to close the project.

2. Click **File | New project** from the main menu.

3. A Create project file dialog will pop up. Within the VIEE++ folder C:\ ISR360_VIEE++_v20180202\misc\Training \Student_exercises folder enter "NWS_MPAR_Ground_Based_Radar" as the project File name. Click Save.

4. The GUI Builder window appears requesting the user to "Select a Template." Click the Blank template.

5. Setting Properties for your scenario:

   a. The Project properties is displayed where the user will fill in general parameters about the overall scenario.

   b. In the "Project name" field name the project "NWS_MPAR_Ground_Based_Radar."

   c. Scroll down to the Surveillance region section and click on the pick on a map icon. In the "Pick on map" window, move the place marks so that the surveillance region looks similar to Figure 16. Click Ok.

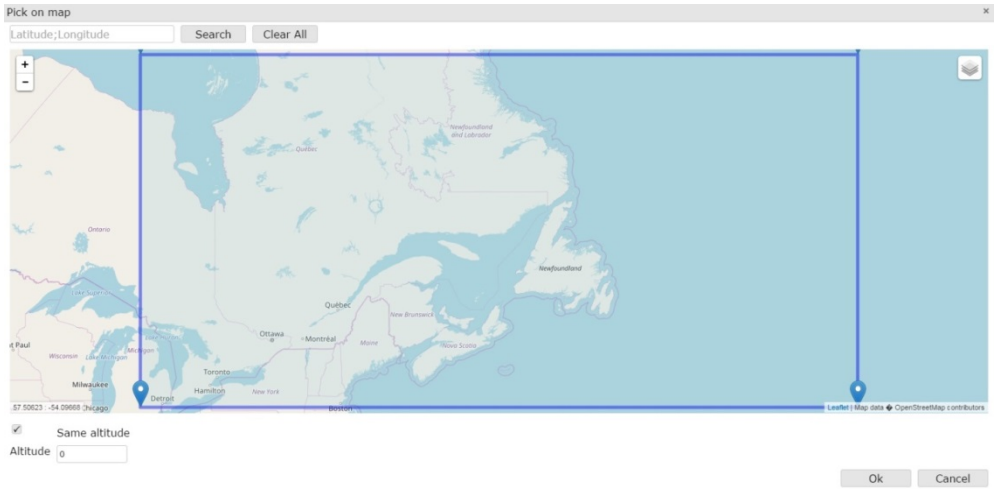


Figure 16: *Project No. 3 "Pick on map" window. (Used with permission from Trackgen Solutions Inc.)*

d. Click the  arrow at the top right of the window to move on to the GUI Builder to create objects for your scenario.

6. Sensor: Drag and drop a new 2D-Radar sensor with the following parameters.

- Name = NWS-LR
- Category = Monostatic_Active
- Type = 3D_Radar
- Position
  - Altitude mode = relativeToGround
  - Latitude = 45.5092342
  - Longitude = -75.5859375
  - Altitude = 30
- Measurements
  - Range
    - Minimum = 185000
    - Maximum = 450000
    - Error standard deviation = 150
  - Bearing
    - Minimum = -180
    - Maximum = 180
    - Error standard deviation = 1

- Elevation
  - Minimum = -5
  - Maximum = 10
  - Error standard deviation = 1
- Additional coverage variables
  - Select “Check line-of-sight”
  - Select “Use terrain for LOS calculation”
- Detection
  - Pfa = 1e-5
  - Disable Constant PD
  - Nominal range SNR
    - Range0 = 370000
    - Sigma0 = 1
    - SNR0 = 10.5

For the second sensor you can use the clone object on the Canvas.

7. Sensor parameters (short range NWS-SR):

- Name = NWS-SR
- Category = Monostatic_Active
- Type = 3D_Radar
- Position
  - Altitude mode = relativeToGround
  - Latitude = 47.62958
  - Longitude = -70.16487
- Measurements
  - Range
    - Minimum = 10000
    - Maximum = 185000
    - Error standard deviation = 150
  - Bearing
    - Minimum = -180

        - Maximum = 180
        - Error standard deviation = 1
    - Elevation
        - Minimum = -5
        - Maximum = 20
        - Error standard deviation = 1
- Detection
    - Nominal range SNR
        - Range0 = 185000

8. Tracker:

    a. Drag and drop an IMM-MFA tracker onto the Canvas.

    b. Change the name to IMM-MFA-NWS.

    c. Make a link[1] from each of the NWS-LR and NWS-SR sensors to the newly added tracker so that tracks will be generated from the NWS radars.

9. Import MPAR sensors:

    a. Click the  from the Top toolbar to import objects from another project.

    b. Navigate to the C:\ISR360_VIEE++_v20180202\misc\Training\Student_exercises directory and select "MPAR_Ground_Based_Radar.360" scenario. Click Open.

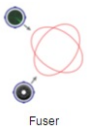
    c. Under Sensor, select both MPAR-LR and MPAR-SR and choose to add the IMM-MFA-MPAR tracker as well. Click Import.

    d. All three objects should appear on your Canvas. Link the MPAR-LR and MPAR-SR to the IMM-MFA-MPAR tracker similar to NWS sensors.

10. Fuser:

    The Fuser will take tracks as input created from 2 or more trackers and build a single "fused" track. On the VIEE map display you have the option to toggle to view the fused track, tracks from each of the trackers or any combination.

[1] See Annex B for all possible VIEE++ object link restrictions.

a. Drag and drop the Fuser 

from the Catalog panel onto the Canvas.

b. Change the name to Fuser-MPAR-NWS.

c. Make a link from each of the tracker outputs (i.e., connect IMM-MFA-NWS tracker and link it to the Fuser object. Do the same for the IMM-MFA-MPAR tracker. You should now have the Fuser object taking tracks as input from both the MPAR and NWS sensors.

11. MOP:

a. Drag and drop the MOP-1 

from the Catalog panel onto the Canvas.

b. In the Properties panel of the MOP object, set the “Maximum position error” to 25000.

12. Target:

a. Click the  from the Top toolbar to import objects from another project.

b. Navigate to the C:\ISR360_VIEE++_v20180202\misc\Training\Exercise_solutions directory and select “NWS_MPAR_Ground_Based_Radar.360” scenario. Click Open.

c. Under Target, select the aircraft. Click Import.

Your scenario in the GUI Builder Canvas should now look like Figure 17.

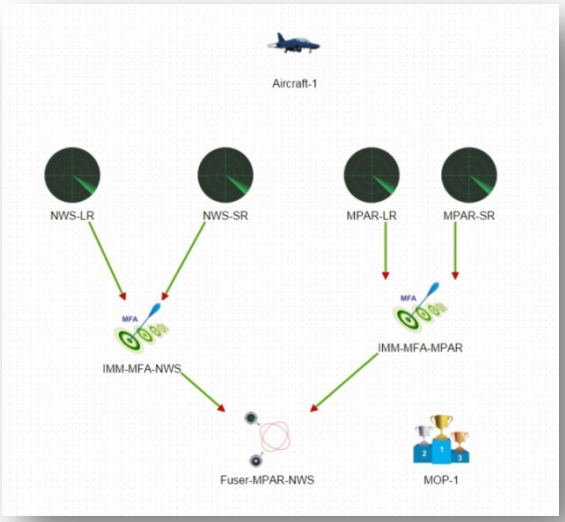


Figure 17: *Project No. 3 VIEE++ canvas. (Used with permission from Trackgen Solutions Inc.)*

13. Save the project. Click **Yes** to reload project.

Note: The instructor will briefly describe the scenario.

2.8 Part 7: Beam Pattern Emulation

2.8.1 Projects No. 4 and No. 5—NAV Canada RAMP Radar and an AESA Radar Respectively

For this project, we will model a NAV Canada RAMP radar and an active electronically scanned array (AESA) radar using two spreadsheet templates with macros in order to calculate the parameters needed to be entered into VIEE++ for the emulation of complex beam patterns that these radars exhibit. Note, with the VIEE++ ISR catalog, if the radars you are interested in have already been modelled, you can simply drag-and-drop it from the Catalog onto your Canvas to use it. The following describes in detail the steps required to model a more complex radar in VIEE++ given that you know the majority of the radar parameters as described below. In the next release of VIEE++ this step should not be required as a beam pattern file will be included as an option for input to your radar.

Radar parameters required for VIEE++:

1. Reference Range: R0
2. Reference RCS: SIGMA0
3. Reference Signal-to-Noise-Ratio: SNR0
4. Number of pulses non-coherently integrated: nnc
5. Probability of False Alarm: Pfa
6. Probability of Detection: Pd
7. Elevation Field of View: FOVe
8. Elevation angle uncertainty: de (e.g., for a pencil beam that doesn't use monopulse processing use ± half of the half power beamwidth)
9. Azimuthal Field of View: FOVa
10. Azimuthal angle uncertainty: da (e.g., ± half of the half power beamwidth)

Problem Statement:

The elevation FOVe provides hard constraints on what the simulated radar "sees." If the target is outside of that FOV it will not be detected (see Figure 18). For a narrow pencil beam where the FOVe could reasonably be represented by the beamwidth (see Figure 18), or where the overall FOVe of the radar could be represented by the composite coverage provided by a number of overlapping pencil beams (e.g., an active phased array radar as in Figure 19) there is not much of a problem using this model. However, if the radar antenna has a more complex beam pattern (a.k.a. gain curve) then, as implied by Figure 20 and Figure 21, setting a single FOVe for the radar will either underestimate or overestimate the radar's overall detection capability. Figure 22 provides a view of a solution to better emulate the radar system's detection

capability over the full effective elevation FOV by segmenting the full FOV into parts of varying width (shown in Figure 22 as FOVe0 and FOVe1).

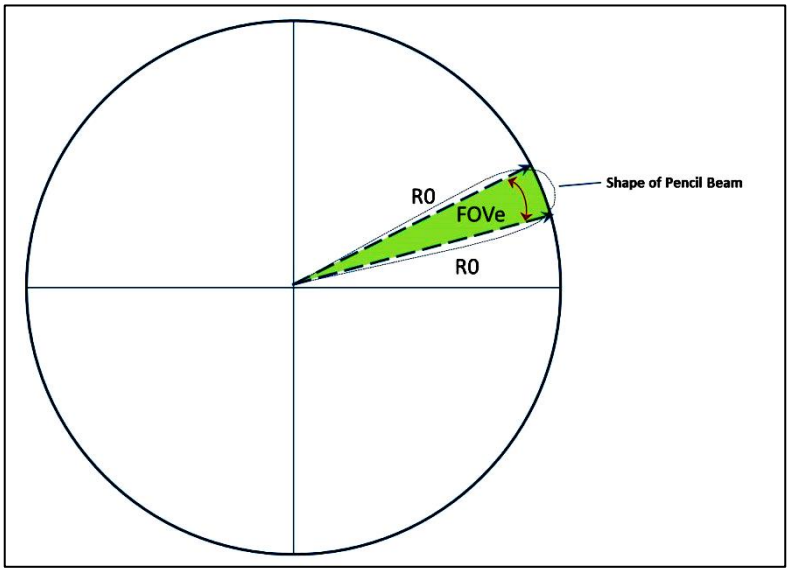


Figure 18: *FOVe (shaded green) relative to pencil beam shape.*

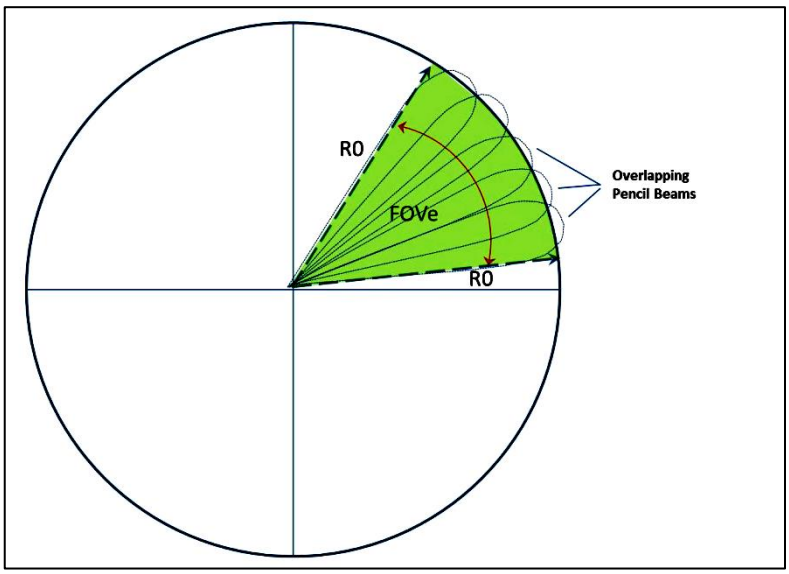


Figure 19: *Overlapping pencil beams of an AESA radar could be reasonably emulated by a uniform FOVe.*

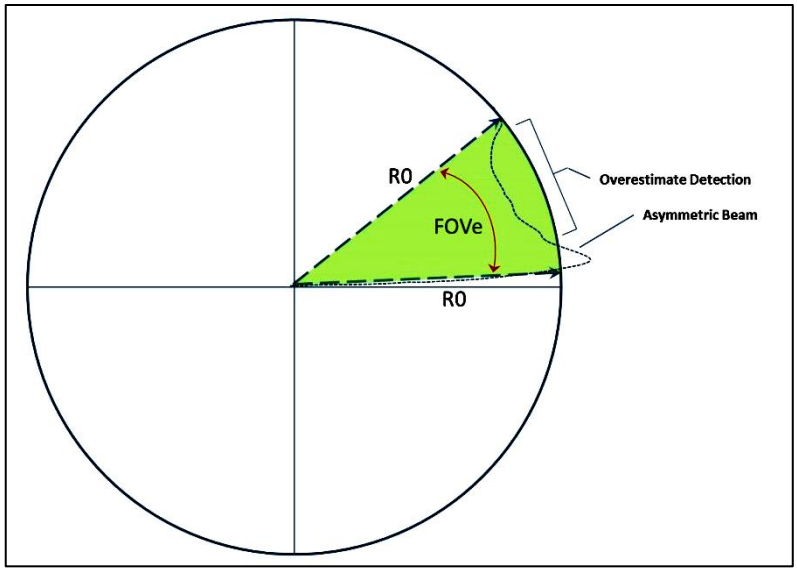


Figure 20: *For an asymmetric beam shape using a single FOVe to represent the relevant portions of radar beam would cause over or underestimates of the detection capability depending on the target elevation angle.*

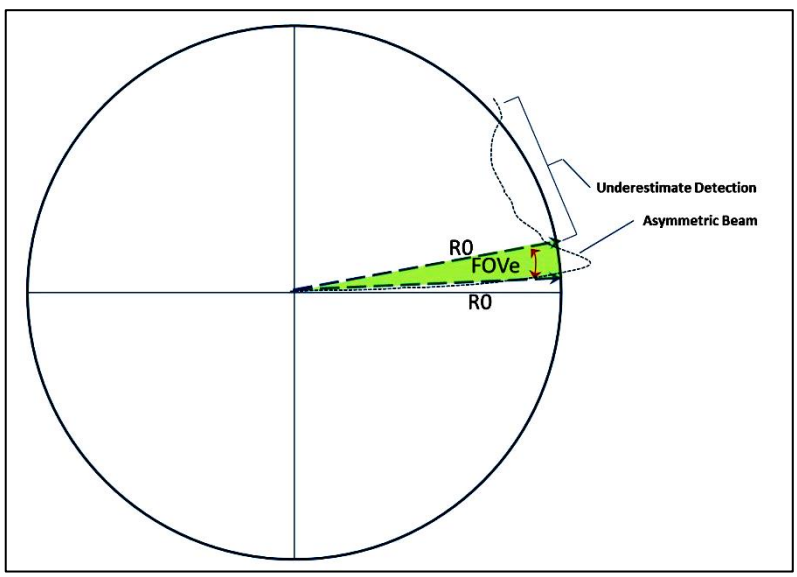


Figure 21: *If you only considered the portion of the beam shape that was equal or greater than the ½ power gain, then the radar capability would be greatly underestimated.*

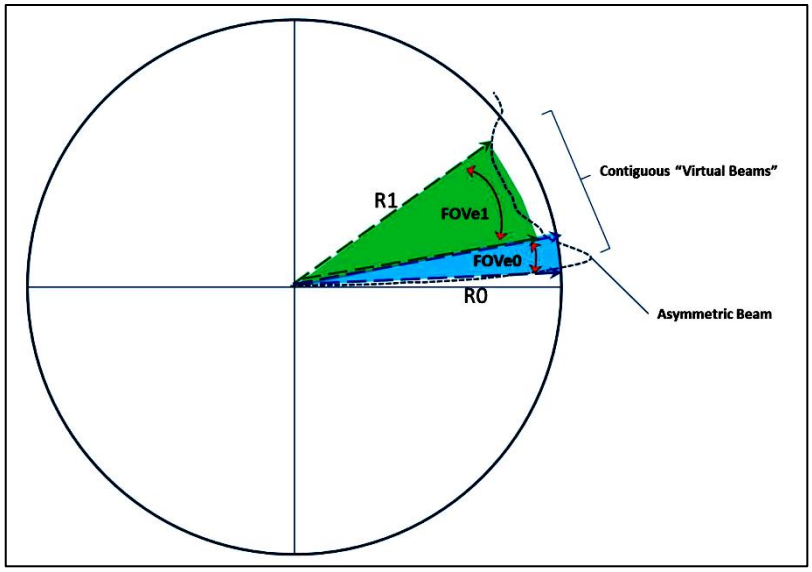


Figure 22: *One solution to emulate the beam shape is to segment the relevant portion of the beam into contiguous "virtual beams" or "virtual subsystem radars" that will be fused in the final simulation.*

Example 1—NAV Canada RYC-8405 (RAMP) ATC Radar:

We will turn to VIEE to use the Import feature to add the RAMP radar which was previously modelled into your project. For more detailed information on how the sensor beams were generated, see Annex C.

1. Click **File | Close project**. Click Yes to close the project.

2. Click **File | New project** from the main menu.

3. A Create project file dialog will pop up. Within the VIEE++ folder C:\ ISR360_VIEE++_v20180202\misc\Training \Student_exercises folder enter "RAMP_Radar" as the project File name. Click Save.

4. The GUI Builder window appears requesting the user to "Select a Template." Click the Blank template.

5. Setting Properties for your scenario:

    a. The Project properties is displayed where the user will fill in general parameters about the overall scenario.

    b. In the "Project name" field name the project "RAMP_Radar."

    c. Scroll down to the Surveillance region section and click on the  pick on a map icon. In the "Pick on map" window, move the place marks so that the surveillance region looks similar to Figure 23. Click Ok.

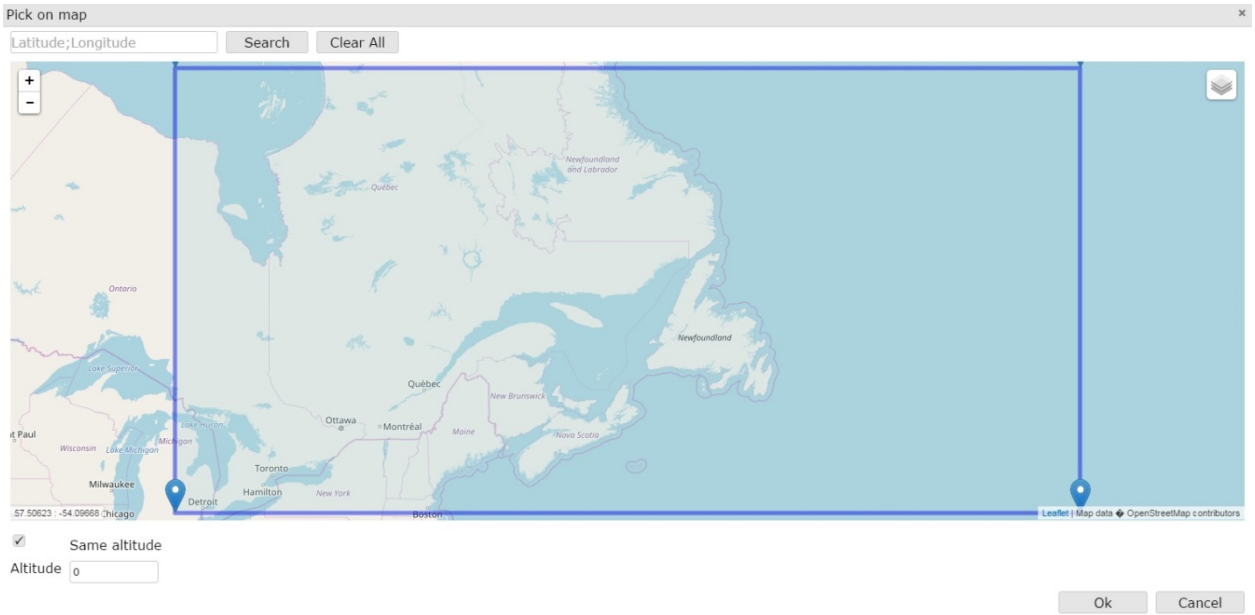


Figure 23: *Project No. 4 "Pick on map" window. (Used with permission from Trackgen Solutions Inc.)*

d. Click the  arrow at the top right of the window to move on to the GUI Builder to create objects for your scenario.

6. Import RAMP radar:

a. Click the  from the Top toolbar to import objects from another project.

b. Navigate to the C:\ISR360_VIEE++_v20180202\misc\Training\Exercise_solutions directory and select "RAMP_radar.360" scenario. Click Open.

c. Click the Select All icon to select all the sensor beams from the RAMP radar, the tracker and the aircraft target.

d. Click Import.

e. All ten sensor objects, one tracker and one aircraft target should appear on your Canvas. Link the 10 sensor objects to the IMM-MFA-1 tracker similar so that only a single track is generated by fusing all the sensor beam detections together.

f. Your project should now look similar to Figure 24.

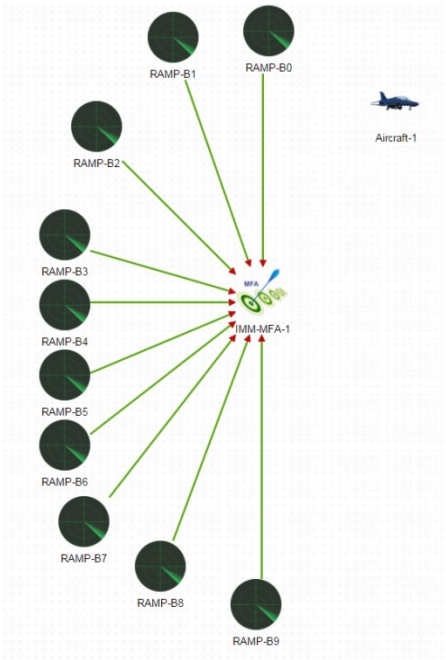


Figure 24: *Screen capture of the VIEE++ GUI model to emulate the beam pattern of a RAMP radar system. All radar beams feed a tracker that will combine the measurements into a single track. (Used with permission from Trackgen Solutions Inc.)*

Note: The instructor will briefly describe the scenario during the training session.

Example 2—AESA Radar System:

The process to follow for this example of an Active Phased Array or Active Electronically Scanned Array (AESA) radar will be similar to the previous one, except that this time the AESA radar has been defined by the individual beams (in this case there are 6 elevation beams) as well as a so-called "composite" beam that one would suppose should be the envelope of the 6 individual beams.

We will now turn to VIEE to use the Import feature to add the AESA radar which was previously modelled into your project. For more detailed information on how the sensor beams were generated, see Annex C.

1. Click **File | Close project**. Click Yes to close the project.

2. Click **File | New project** from the main menu.

3. A Create project file dialog will pop up. Within the VIEE++ folder C:\ ISR360_VIEE++_v20180202\misc\Training \Student_exercises folder enter "AESA_Radar" as the project File name. Click Save.

4. The GUI Builder window appears requesting the user to "Select a Template." Click the Blank template.

5. Setting Properties for your scenario:

a. The Project properties is displayed where the user will fill in general parameters about the overall scenario.

b. In the “Project name” field name the project “AESA_Radar.”

c. Scroll down to the Surveillance region section and click on the  pick on a map icon. In the “Pick on map” window, move the place marks so that the surveillance region looks similar to Figure 25 Click Ok.

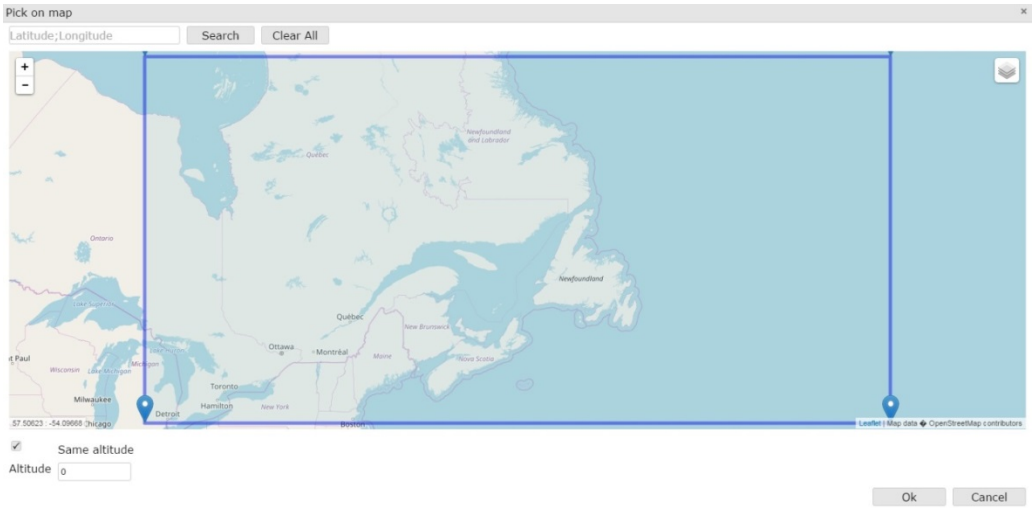


***Figure 25**: Project No. 5 “Pick on map” window. (Used with permission from Trackgen Solutions Inc.)*

d. Click the  arrow at the top right of the window to move on to the GUI Builder to create objects for your scenario.

6. Import AESA radar:

a. Click the  from the Top toolbar to import objects from another project.

b. Navigate to the C:\ISR360_VIEE++_v20180202\misc\Training\Exercise_solutions directory and select “AESA_radar.360” scenario. Click Open.

c. Click the Select All icon to select all the sensor beams from the AESA radar, the tracker and the aircraft target.

d. Click Import.

e. All ten sensor objects, one tracker and one aircraft target should appear on your Canvas. Link the six sensor objects to the IMM-MFA-1 tracker similar so that only a single track is generated by fusing all the sensor beam detections together.

f. Your project should now look similar to Figure 26.

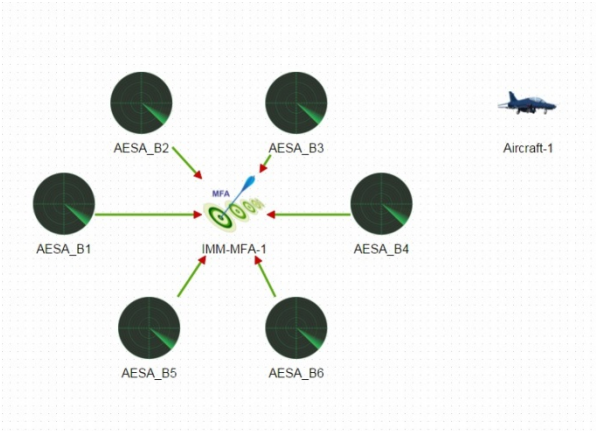


Figure 26: *Screen capture of the VIEE++ GUI model to emulate the beam pattern of a AESA radar system. All radar beams feed a tracker that will combine the measurements into a single track. (Used with permission from Trackgen Solutions Inc.)*

Note: The instructor will briefly describe the scenario during the training session.

2.9 Part 8: Complex Multi-Sensor Multi-Domain Scenario

This scenario consists of two Over the Horizon radars, two High Frequency Surface Wave radars, one active underwater sonar, one passive underwater sonar, two satellites with sensors, UAV, air and ship targets. See Figure 27 for VIEE++ map display of the scenario.

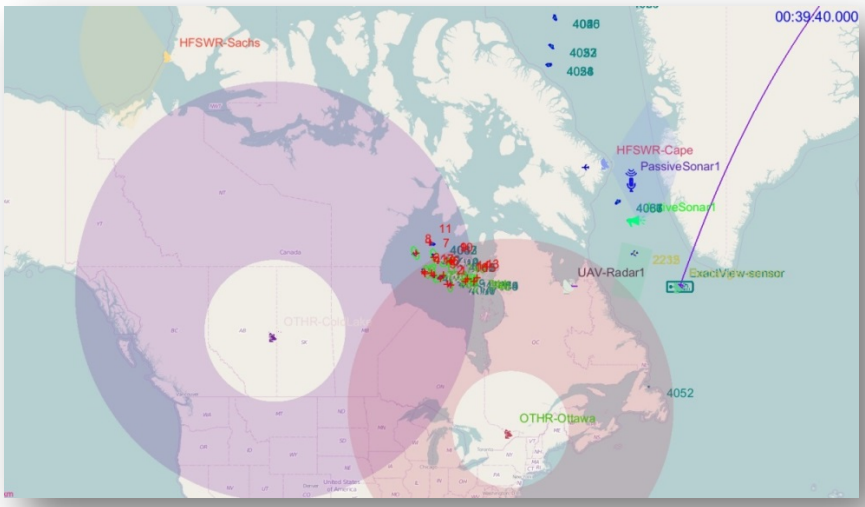


Figure 27: *VIEE++ map display of a complex multi-sensor multi-domain scenario. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

1. Click **File | Close project**.

2. Click **File | Open project** from the main menu.

3. Within the *VIEE++ folder* C:\ISR360_VIEE++_v20180202\misc\projects20151101\Exercise_solutions folder select ArcticSurveillance.360 and click Open.

Note: The instructor will briefly describe the scenario during the training session.

2.10 Part 9: Coverage/Detection plots

This section will explore the coverage/detection plotting capability in VIEE++ which helps visualize sensor performance. Below are some of the plots that can be created using the various plotting options in VIEE++ for coverage and line of sight.

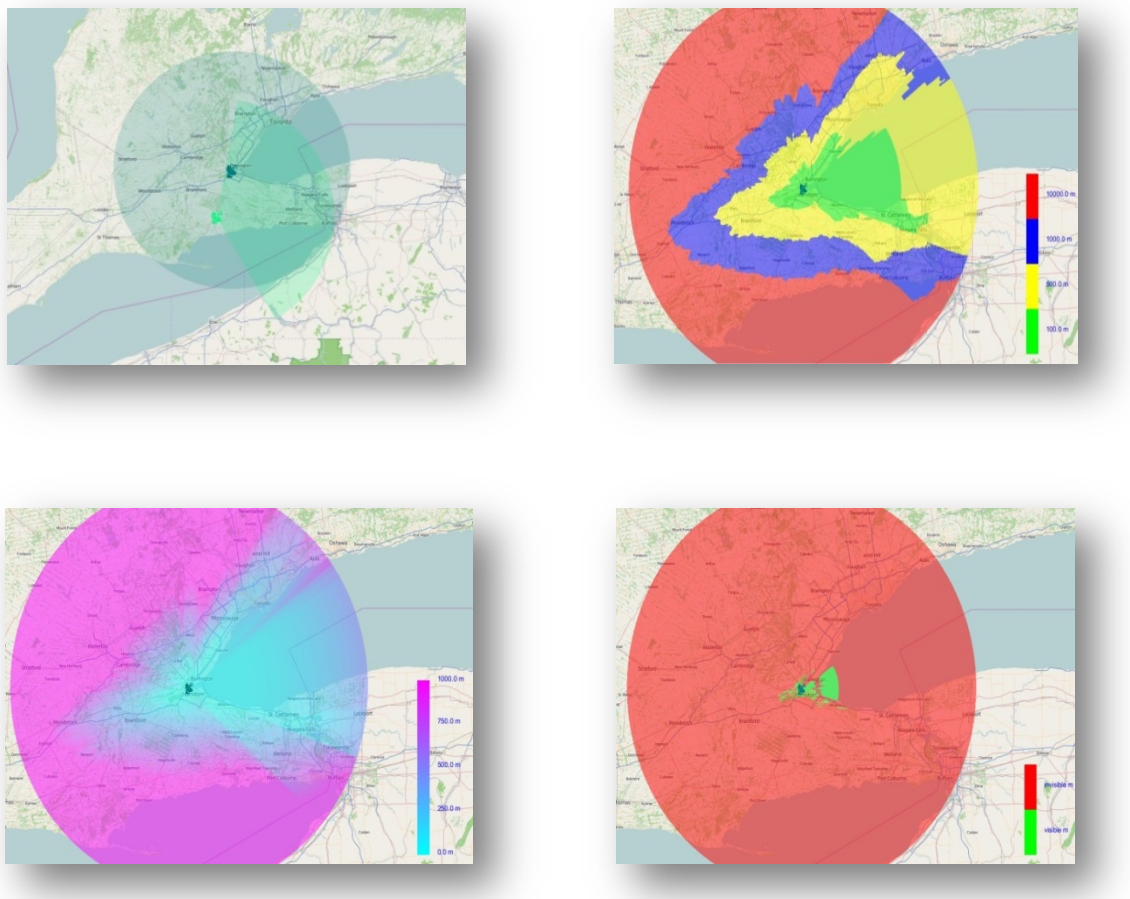


Figure 28: *VIEE++ coverage and line of sight plots.(Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

1. Field of View:

   a. Click **File | Close project**.

   b. Click **File | Open project**. Select the project folder "C:\ ISR360_VIEE++_v20180202\misc\Training \Exercise_solutions" and project named "LosTest.360." Click Open.

c. Click **View | Property panel**.

d. Under the General tab, select Legend which is within the Display options.

e. Select the Measurements tab within this panel.

f. Click Coverage and ensure the Coverage type is Field-of-view. A Field of View coverage display is shown in Figure 29.

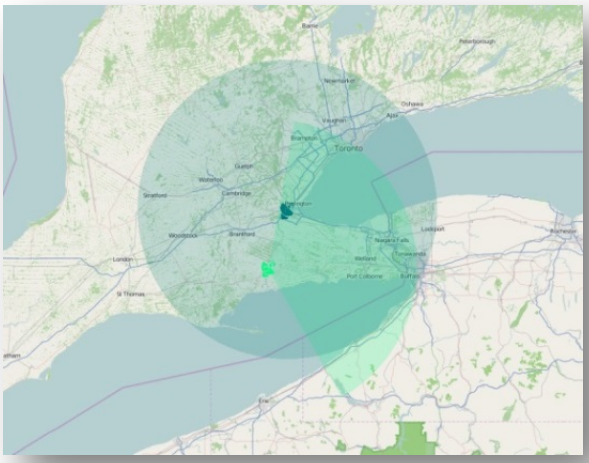


Figure 29: *VIEE++ sensor Field of View. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

2. Line of Sight (LOS):

   a. Continuing from the previous step.

   b. Click Line-of-sight under Coverage Options (see Figure 30).

   This calculation is based on the level of DTED and the surveillance region selected for the scenario. If you select a large surveillance region (i.e., over 200 km), it will take some time to generate the plot. Only include the region of interest as your surveillance region for this calculation to ensure unnecessary LOS calculations are not made.

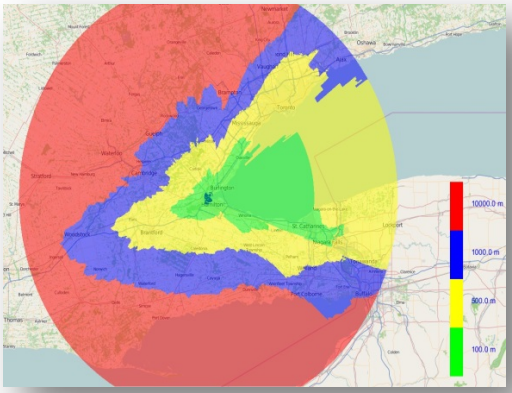


Figure 30: *VIEE++ Line of sight coverage view for targets at altitudes 100 m, 500 m, 1000 m and 10000 m. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

c. Three LOS options are available:

   i. Discrete

   ii. Continuous

   iii. Viewshed

d. Two LOS height types are provided:

   i. Above Ground Level (AGL)

   ii. Mean Seal Level (MSL)

e. Two Multisensor view are offered:

   i. Overlay

   ii. Merge

3. Probability of Detection:

   a. From the Properties panel, under the Management tab, select Probability of Detection under the Coverage Type. The Pd rings are shown in Figure 31.

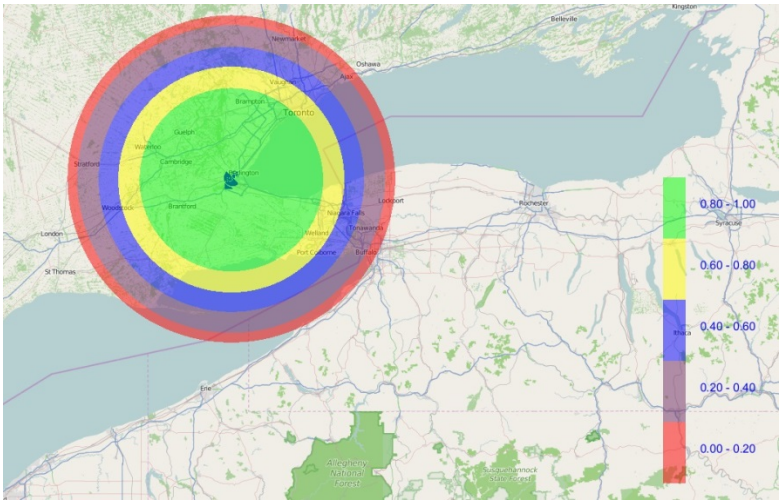


Figure 31: *VIEE++ Probability of detection rings coverage map. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

b. This plot is created from the values entered for the Detection parameters for the sensor as shown in Figure 32.

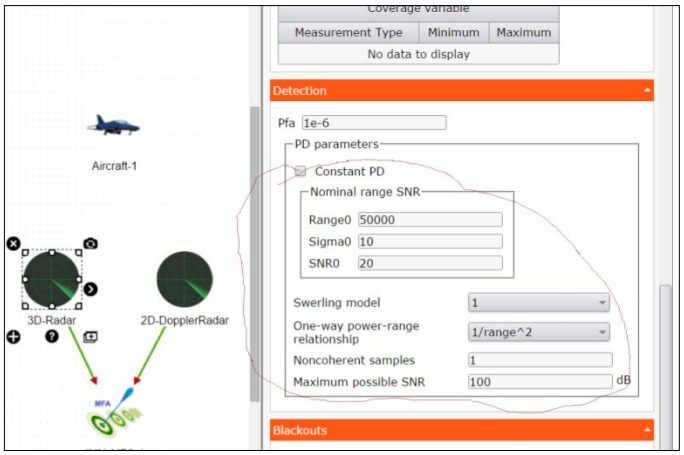


Figure 32: *VIEE++ Radar detection parameters. (Used with permission from Trackgen Solutions Inc.)*

4. Line-of-sight with PD rings:

a. Under Coverage option select Line-of-sight with Pd rings. Notice, Figure 33 below combines both the Line-of-sight and overlays the Pd rings.

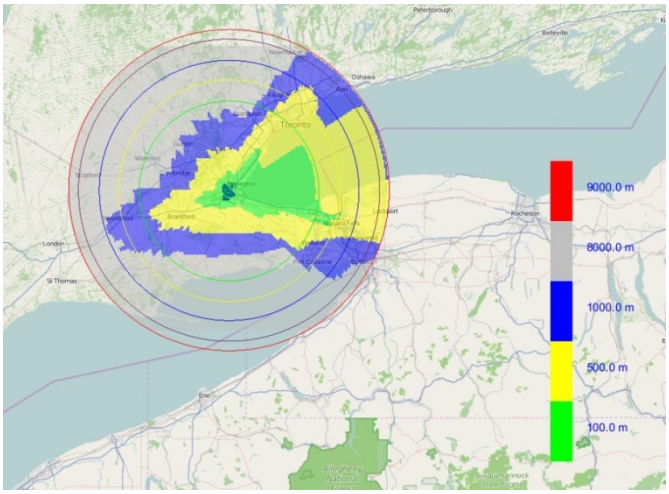


Figure 33: *VIEE++ Line of sight with Pd rings coverage map. (Used with permission from Trackgen Solutions Inc. Map data © OpenStreetMap contributors.)*

5. Change default LOS values:

   a. Click **Edit | project**.

   b. When the GUI Builder window appears, click the Project Settings  icon on the Top toolbar.

   c. Scroll down to the Plotting options section.

   d. There are three Sensor LOS coverage types: Discrete, Continuous, and Viewshed. By selecting one of these types, the display options automatically switch based on your selection.

   e. When you edit the type of your choice, click Save project  and review the update using the Properties panel under the Measurements tab.

2.11 Part 10: Other Features

1. Monte Carlo:

   VIEE++ can run your scenario more than once in a Monte Carlo fashion so that you do not have to base your results on a single run only.

   a. Click **File | Close project**.

   b. Click **File | Open project**. Select the project from Part 4 named "Single_Ground_Based_Radar.ISR360" from C:\ ISR360_VIEE++_v20180202\misc\Training\Student_exercises folder.

   c. Click **Edit | Project**.

   d. When the GUI Builder window appears, click the Project Settings icon on the Top toolbar.

   e. In the Property panel:

      i. Set the Monte Carlo runs to "2."

      ii. Under the Duration section, deselect "Duration from data" and enter 3600 as the "Duration."

   f. Click Save project .

   g. Run your scenario and this time you should see the simulation end after 1 hour simulation time and restart. At the end of the Monte Carlo simulation, the results will be averaged.[2]

   To speed up the simulation, within the Property panel | General tab, enable Silent mode. This will run the simulation without the graphics being updated. You could do this if you have configured your scenario the way you want and want to run it in a batch mode.

2. Saving the plot:

   There are 2 ways to save images of your scenario. From the Main toolbar:

[2] The majority of the metrics are averaged over all runs, however there are some metrics which take an overall maximum value over all the runs.

Saves the current plot, defaulting to .png file.

Saves the current screen, defaulting to .png file.

3. Export data:

VIEE++ has a feature which allows the user to export data for further processing. The data could be output to a csv and enable the user to create a chart in a presentation for example.

a. Click **File | Close project**.

b. Click **File | Open project**. Select the project from Part 6 named "NWS_MPAR_Ground_Based_Radar.ISR360" from the C:\ ISR360_VIEE++_v20180202\Student_exercises folder.

c. Click **View | Property panel**. Click Start under the General tab. Pause the simulation when the target is no longer visible in the scenario.

d. Click **File | Export | MOP**.

This will bring up a dialog to export all the metrics the user is interested in.

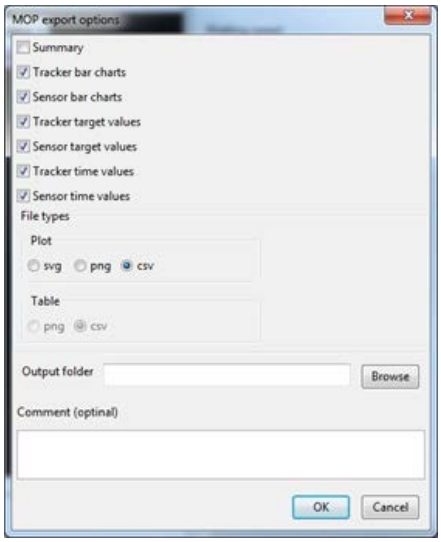


Figure 34: *VIEE++ measures of performance export options. (Used with permission from Trackgen Solutions Inc.)*

e. Select the bottom four checkboxes as indicated in the figure above.

f. Click the csv Plot file type.

g. Click Browse and set the folder to your C:\ISR360_VIEE++_v20180202\Student_exercises\Output and click "Select folder." This will export all metrics of interest to the output folder.

How persistent can you track the target of interest?

You may want to consider using the following metrics to answer this:

- Tracklife
- Maximum gap in track in scenario
- Track probability of detection in scenario
- Track confirmation latency in scenario

A subset of the exported bar charts found in ..\Output\target_bar_charts are shown here:

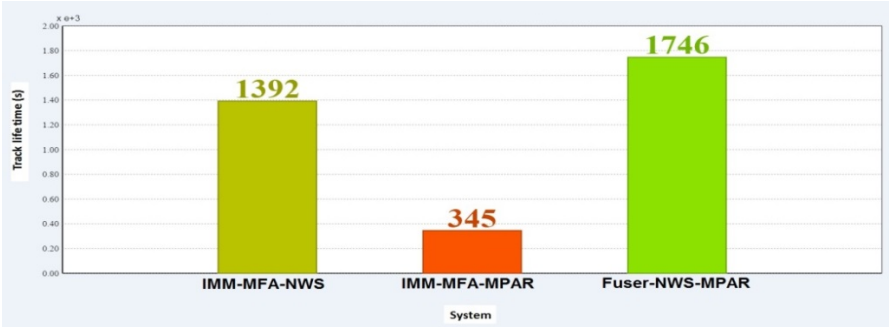


Figure 35: *Track life time metric.*

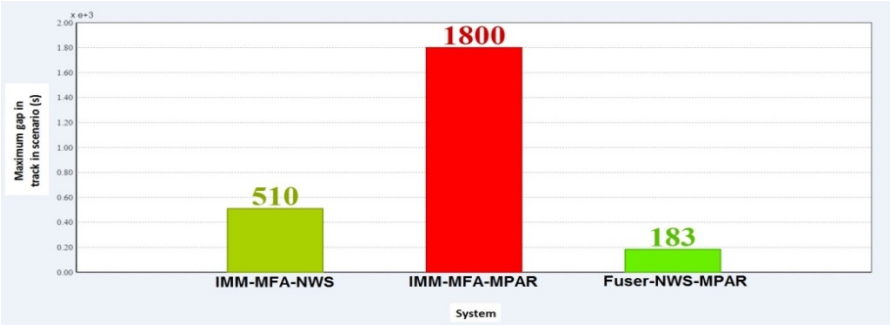


Figure 36: *Maximum gap in track in scenario metric.*

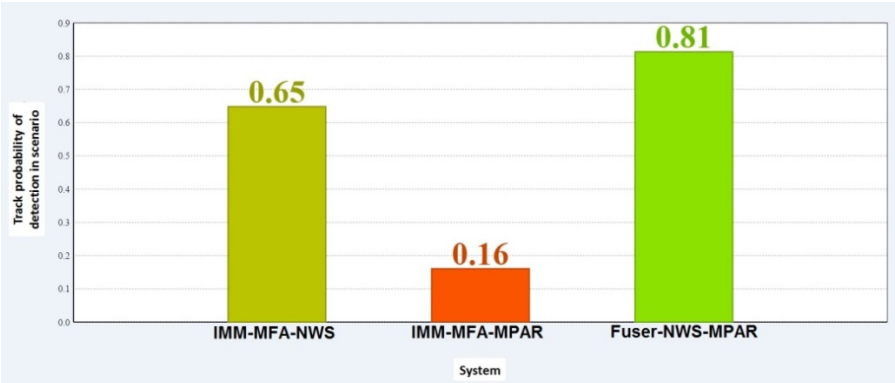


Figure 37: *Track probability of detection in scenario metric.*

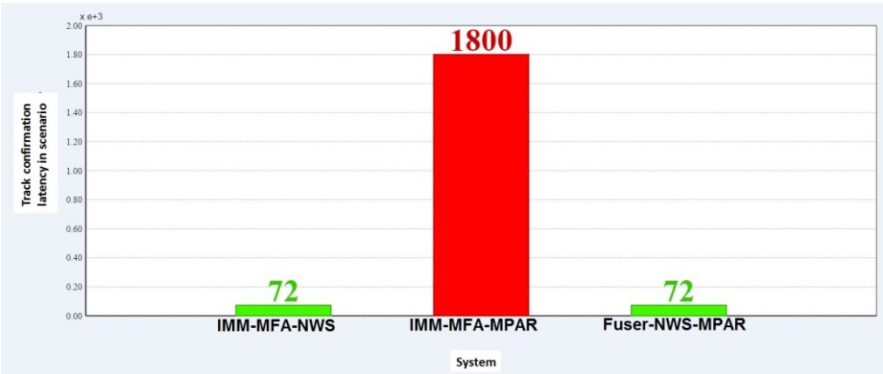


Figure 38: *Track confirmation latency in scenario metric.*

4. Display DTED map:

   a. Click **View | Property panel**.

   b. Within this panel, under Background tab, ensure Map selection is set to Basemap, then select DTED as well. It may take a few seconds to appear. A DTED level 0 map overlaid onto of the Basemap appears similar to the Figure 39.

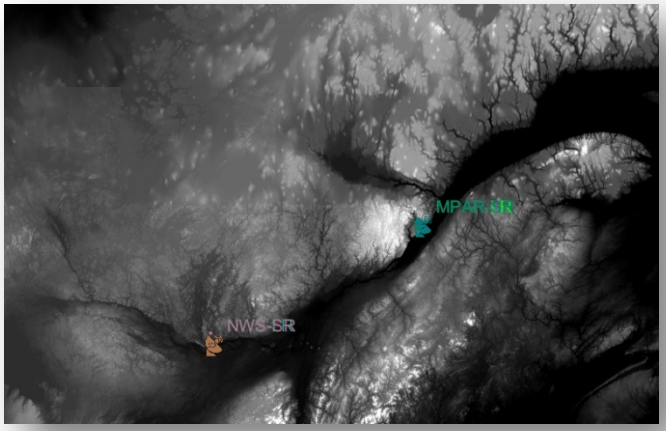


Figure 39: *VIEE++ DTED level 0 overlaid on 2D map display.*
(Used with permission from Trackgen Solutions Inc.)

References

[1] Trackgen Solutions, VIEE++ User Manual. (2018).

[2] Gorji, A.A., Tharmarasa, R., & Kirubarajan, T., Performance measures for multiple target tracking problems. 14th International Conference on Information Fusion, 1–8, (2011).

[3] Neuvy, J., An Aspect of Determining the Range of Radar Detection, IEEE Trans. Aero. Elec. Sys., Vol. AES-6, No. 4, (1970).

Annex A Metric Definitions

Metrics in Table A.1 and Table A.2 were compiled from [1], [2].

Table A.1: *VIEE++ sensor metric definitions.*

Sensor metrics	Definition
SensorPD_Scn	The number of frames with detections divided by the total number of frames.
SensorPD_FOV	The number of frames with detections divided by the total number of frames within the sensor Field of View.
SensorPD_AOI	The number of frames with detections divided by the total number of frames within the Area of Interest(s).
AvgDetectionGap	Average of interval between the detections from a target. The first gap is the interval between first detection time and the time at which the target entered the sensor coverage. The last gap is the interval between the last detection time and the time at which the target leaves the sensor coverage.
AvgDetectionGap_Scn	Average of interval between the detections from a target. The first gap is the interval between first detection time and the target start time. The last gap is the interval between the last detection time and the target end time.
AvgDetectionGap_AOI	Average of interval between the detections from a target. The first gap is the interval between first detection time and the time at which the target entered the sensor coverage. The last gap is the interval between the last detection time and the time at which the target leaves the Area of Interest(s).
MinDetectionGap	Minimum value of detection gaps. The definition of gap is same as in the "AvgDetectionGap."
MinDetectionGap_Scn	Minimum value of detection gaps. The definition of gap is same as in the "AvgDetectionGap_Scn."
MinDetectionGap_AOI	Minimum value of detection gaps. The definition of gap is same as in the "AvgDetectionGap_AOI."
MaxDetectionGap	Maximum value of detection gaps. The definition of gap is same as in the "AvgDetectionGap."
MaxDetectionGap_Scn	Maximum value of detection gaps. The definition of gap is same as in the "AvgDetectionGap_Scn."
MaxDetectionGap_AOI	Maximum value of detection gaps. The definition of gap is same as in the "AvgDetectionGap_AOI."

Table A.2: *VIEE++ tracking metric definitions.*

Tracking metrics	Definition
RMSE	See [2].
AvgEucError	See [2].
AvgGeomError	See [2].
AvgHarmError	See [2].
CumBroken	Number of breaks in tracks.
TrackContunuity	The ideal case in MTT problems is to assign a unique track to every truth while the truth is alive. In this case, the truth is said to be tracked 100% continuously. However, if there is any break or swap in the estimated tracks assigned to the truths, the continuity measure varies between 0 and 100%.
TrackFragment	The rate of which the tracking algorithm fragments tracks.
ConfLatencyScn	Track confirmation latency is defined as the time lag between the first time that the target appears and the time that the target has been associated with a valid track.
ConfLatencyFOV	Track confirmation latency is defined as the time lag between the first time that the target appears and the time that the target has been associated with a valid track within the sensor Field of View.
ConfLatencyAOI	Track confirmation latency is defined as the time lag between the first time that the target appears and the time that the target has been associated with a valid track within the Area of Interest(s).
TrackPD_Scn	Track probability of detection is defined as the ratio between the life time of associated track(s) and the target life time.
TrackPD_FOV	Track probability of detection is defined as the ratio between the life time of associated track(s) and the target life time inside the sensor Field of View.
TrackPD_AOI	Track probability of detection is defined as the ratio between the life time of associated track(s) and the target life time inside the Area of Interest(s).
AvgTrackGap_Scn	Average value of gaps in validated tracks. The first gap is the interval between the first assigned track time and the target start time. The last gap is the interval between the last assigned track time and the target termination time.
AvgTrackGap_FOV	Average value of gaps in validated tracks. The first gap is the interval between the first assigned track time and the target start time. The last gap is the interval between the last assigned track time and the target termination time within the sensor Field of View.
AvgTrackGap_AOI	Average value of gaps in validated tracks. The first gap

Tracking metrics	Definition
	is the interval between the first assigned track time and the target start time. The last gap is the interval between the last assigned track time and the target termination time within the Area of Interest(s).
MaxTrackGap_Scn	Maximum value of gaps. The definition of gap is same as in the "AvgTrackGap_Scn."
MaxTrackGap_FOV	Maximum value of gaps within sensor Field of View. The definition of gap is same as in the "AvgTrackGap_FOV."
MaxTrackGap_AOI	Maximum value of gaps within Area of Interest(s). The definition of gap is same as in the "AvgTrackGap_AOI."
MinTrackGap_Scn	Minimum value of gaps. The definition of gap is same as in the "AvgTrackGap_Scn."
MinTrackGap_FOV	Minimum value of gaps within sensor Field of View. The definition of gap is same as in the "AvgTrackGap_FOV."
MinTrackGap_AOI	Minimum value of gaps within Area of Interest(s). The definition of gap is same as in the "AvgTrackGap_AOI."
TotalTrackGap_Scn	The sum of all gaps in validated tracks.
TotalTrackGap_FOV	The sum of all gaps in validated tracks within sensor Field of View.
TotalTrackGap_AOI	The sum of all gaps in validated tracks within Area of Interest(s).
ContTracks	Number of unique tracks that are validated with a target.
GatedTracks	Average number of tracks falls inside the association gate.
TrackLife	The total duration of validated tracks for a target.

Annex B VIEE++ Object Restrictions

Table B.1 shows the VIEE++ object restrictions and can be found in [1].

Table B.1: *VIEE++ object restrictions. (Used with permission from Trackgen Solutions Inc.)*

Object		Links: Possible input link from	Links: Possible output link to	Remarks
Target	Target simulator		Target publisher	
	Target from data	Target provider	Target publisher	At least one input is required.
	Target provider		Target from data	At least one output is required.
	Target publisher	Target simulator Target from data		At least one input is required.
Platform	Platform simulator	Sensor measurement level simulator Sensor rawdata simulator Sensor from data	Platform state publisher	
	Platform from data	Sensor measurement level simulator Sensor rawdata simulator Sensor from data Platform state provider	Platform state publisher	At least one input is required.
	Platform state provider		Platform from data	At least one output is required.
	Platform state publisher	Platform simulator Platform from data		At least one input is required.
Sensor	Sensor measurement level simulator		Measurement publisher Tracker online Platform simulator Platform from data MOP	
	Sensor rawdata simulator		Rawdata publisher Measurement publisher Tracker online Platform simulator Platform from data MOP	
	Sensor from data	Rawdata provider Measurement provider	Rawdata publisher Measurement publisher Tracker online Platform simulator Platform from data MOP	At least one input is required.
	Rawdata provider		Sensor from data	At least one output is required.
	Rawdata publisher	Sensor rawdata simulator Sensor from data		At least one input is required.
	Measurement provider		Sensor from data	At least one output is required.

			Classifier MOP	linked.
Track processor	Classifier	Tracker online Tracker from data Fuser online Fuser from data	Tracker online Tracker from data Fuser online Fuser from data	
	Predictor	Tracker online Tracker from data Fuser online Fuser from data	Tracker online Tracker from data Fuser online Fuser from data	
MOP				Can have only one instance
Guardzone				
Waypoint				

Annex C Beam Pattern Emulation

Example 1—NAV Canada RYC-8405 (RAMP) ATC Radar:

Process:

1. First determine the values required for the radar parameters listed earlier; some can be found outright and others may need to be derived. For example: if you know the desired Pfa, and the desired Pd at the maximum detection range, as well as the number of pulses that are non-coherently integrated (i.e., nnc) and the type of Swerling model used for simulating the RCS statistical distribution, then there is a set of equations by Neuvy [3] that can be used to determine the minimum detectable SNR required (this will be the SNR0 parameter in VIEE++). An Excel file is provided with this course that can be used to do the calculations. It is called **Neuvy_DetectabilityFactorCalculator.xlsx**. A screen capture of the spreadsheet is shown in Figure C.1.

	A	B	C	D	E	F	G	H
1	Swerling Case	Pfa	Pd	nnc	alpha	beta	Detectability Factor	Detectability factor (dB)
2	0	1.00E-06	0.6	1	2.433063	0.166667	18.26493024	12.61618018
3	1	1.00E-06	0.5	12	0.674807	1	2.497985076	3.975898395
4	2	1.00E-07	0.77	1	1	0.883198	46.74152857	16.69702911
5	3	1.00E-06	0.86	1	1.108266	0.666667	39.83673386	16.00283724
6	4	1.00E-06	0.98	1	1	0.40551	39.85938334	16.00530575

Figure C.1: *Screen capture of the Neuvy_DetectabilityFactorCalculator spread sheet that can be used to determine SNR0 (i.e., Detectability Factor (dB)), based on the desired Pd, Pfa, and the nnc value for the radar system. Note: Swerling Case 0 is for a constant RCS, and for most air targets we will be using Swerling Case 1.*

In many cases the radar is designed such that it will have a Pd of 0.5 at or near the maximum range (R0), for a target with a RCS of 1.0 m^2. So far, we have determined our values for Pd, Pfa, nnc, SNR0, and RCS0 (a.k.a. Sigma0) for our radar system, and now we need to derive the value for the reference range R0. In order to estimate R0 this will be done by using one version of the so-called Radar Range Equation, but it will require additional system specifications such as the following:

a. Peak transmitter power (Pt in kW);

b. Pulse length (PL in microseconds);

c. Maximum gain of the transmitter antenna (Gr in dB);

d. Maximum gain of the receiver antenna (Gt in dB);

e. Effective radar system temperature (Ts in °Kelvin);

f. Operating frequency (Hz);

g. Combined sum of all loss factors.

These values may be found by consulting a database such as the one available in the RADES Explorer (part of the RS4 software package) which was developed by the U.S.' 84th Radar Evaluation Squadron (hence RADES). It will provide the values of all the relevant parameters, as well as the radar system's beam pattern (in most cases). The RADES explorer will also provide its own estimates of R0 and Pd as a function of R0. (note, this is also where we can find the value for nnc). If such a comprehensive database is not available, then other open sources, such as the internet, may be used to obtain some parameters, and others may need to be approximated.

In order to facilitate this work, a radar range calculator spreadsheet was created in Excel, and can be used for any calculations that we will need going forward; it is called **Reference_Range_Calculator.xls** as shown in Figure C.2.

	A	B	C	D	E	F	G	H	I	J	K
1											
2		**Peak Power (kW)**	**Pulse Width (microsec)**	**Receiver Gain(dB)**	**Transmitter Gain (dB)**	**Frequency (MHz)**	**RCS (sqm)**	**-SNR0 (dB)**	**System Temperature (deg. K)**	**Total Loss Factors(dB)**	**Lumped constants**
3	value in given units	25	100	33.5	33.5	1300	2	-17.75	600	-3	3.65167E+19
4	relevant value converted to dB	43.97940009	-40	33.5	33.5	-12.73644195	2	-17.75	-27.7815125	-3	195.6249132
5	total	207.3363588									
6	Reference Range R0	152548.8616									
7	If R0 given, doesn't need calc.	Enter value for R0	150000								
8		Reference Range R1	115768.7273	down 4.5 dB							
9		Reference Range R2	97407.24474	down 7.5 dB							
10		Reference Range R3	81957.98248	down 10.5 dB							
11		Reference Range R4	68959.04828	down 13.5 dB							
12		Reference Range R5	58021.80819	down 16.5 dB							
13		Reference Range R6	48819.26752	down 19.5 dB							
14		Reference Range R7	41076.29451	down 22.5 dB							
15		Reference Range R8	34561.39464	down 25.5 dB							
16		Reference Range R9	29079.78954	down 28.5 dB							
17											
18		**Gain Reduction (dB)**	**R0 (m)**	**RN(m)**							
19	Adjusted **R0** (i.e. **RN**) for arbitrary gain reduction	9	150000	89349.32153							
20											

Figure C.2: *Screen capture of the Reference_Range_Calculator spreadsheet using Excel. This is a typical example of how to use the calculator, but we will use these values later in the example. Except for R1, each of the sequential reference ranges show below R0 is for additional 3 dB drops (amount indicated) from R0.*

2. The next step in building the radar model is to determine the actual field of view (see Figure C.3) that is required for the final radar simulation; i.e., the minimum and maximum elevation angles required in the simulation. If there are assumed to be constraints on the maximum and minimum target altitude, then these will constrain the overall FOVe.

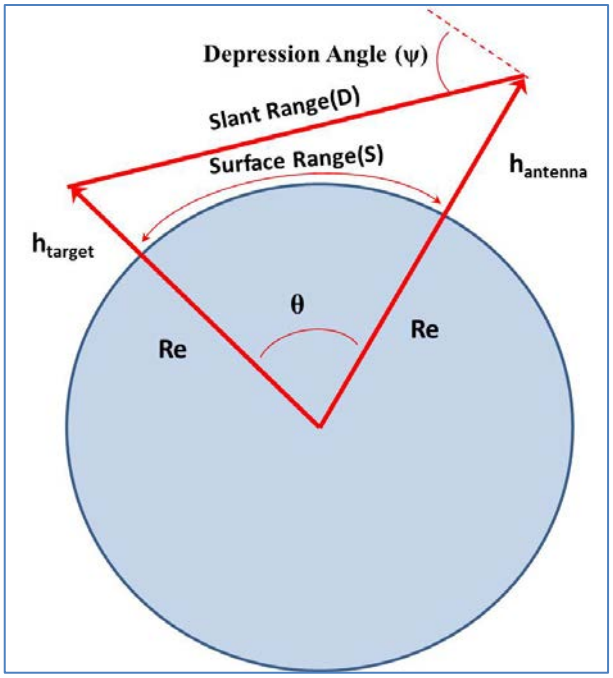


Figure C.3: *Determining the FOV geometry based on the target altitude constraints.*

The Maximum observable slant range (D_{max}) assuming a smooth spherical Earth is the combined observation distance to the horizon from the antenna and from the target and is given by Equation (C.1) below:

$$D_{max}=\left[\left(h_{target}+Re\right)^2-Re^2\right]^{1/2}+\left[\left(h_{antenna}+Re\right)^2-Re^2\right]^{1/2} \tag{C.1}$$

The corresponding maximum value for **θ** and S is given by Equation (C.2):

$$\theta_{max}=\cos^{-1}\left[\frac{Re}{\left(h_{target}+Re\right)}\right]+\cos^{-1}\left[\frac{Re}{\left(h_{antenna}+Re\right)}\right] \tag{C.2}$$

$$S_{max}=Re\cdot\theta_{max}=Re\cdot\left\{\cos^{-1}\left[\frac{Re}{\left(h_{target}+Re\right)}\right]+\cos^{-1}\left[\frac{Re}{\left(h_{antenna}+Re\right)}\right]\right\} \tag{C.3}$$

Using the laws of sines and cosines for a planar triangle, the following can be shown:

$$\psi(\text{degrees})=90-\sin^{-1}\left[\frac{\left(h_{target}+Re\right)}{D}\cdot\sin\left(\frac{S}{Re}\right)\right] \tag{C.4}$$

$$=90-sin^{-1}\left[\frac{\left(h_{target}+Re\right)}{\left[\left(h_{target}+Re\right)^2+(h_{antenna}+Re)^2-2\left(h_{target}+Re\right)(h_{antenna}+Re)\cdot\cos\left(\frac{S}{Re}\right)\right]^{1/2}}\cdot\sin\left(\frac{S}{Re}\right)\right] \quad (C.5)$$

If the target altitude is higher than the radar antenna altitude, then there will be a crossover point, from positive to negative depression angle, as the target approaches the radar. It can be shown that the crossover point will occur when the surface range S is given by the formula provided in Equation (C.6):

$$S=Re\cdot\cos^{-1}\left[\frac{\left(h_{antenna}+Re\right)}{\left(h_{target}+Re\right)}\right] \quad (C.6)$$

Equation (C.6) is verified in the graph on the right side of Figure C.4 where it shows the crossover range for a target at 10 km ASL and an antenna altitude of 4.5 km ASL to occur at about 265 km. Based on these arguments, the constraints on the FOVe for the three target altitudes considered in Figure C.4 are as shown in Table C.1.

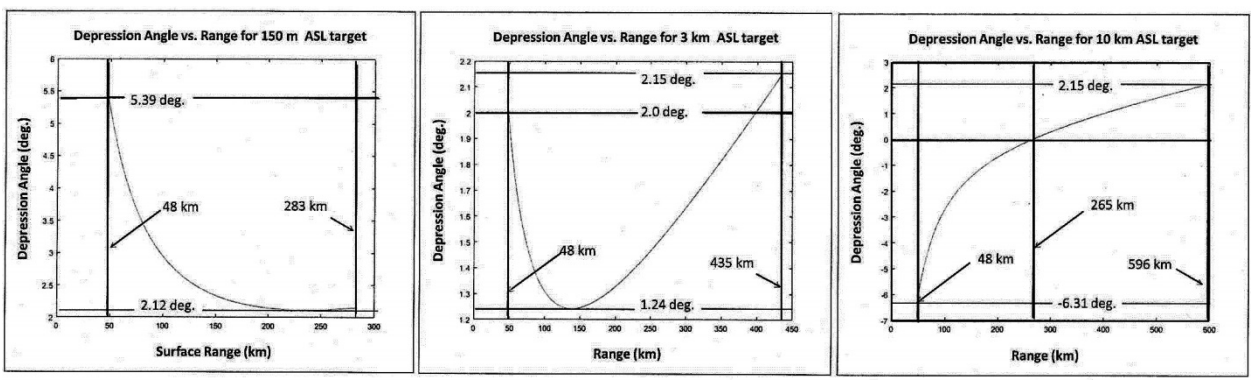


Figure C.4: *This sequence of plots shows how the depression angle varies as a function of range for an aerostat based radar system (like TARS or JLENS) at a constant maximum altitude of about 4500 m (14764 ft), for three different target altitudes (i.e., 150 m ASL, 3000 m ASL and 10000 m ASL) and assuming the radar is in a long range detection mode that starts at 48 km and extends to the maximum observation range dictated by the target-horizon-antenna geometry. (Note: a negative depression angle represents a positive elevation angle.)*

Table C.1: *Maximum and minimum observable elevation angles, assuming a smooth Earth, and the given constraints on the target altitude and range.*

Target Altitude (m ASL)	Minimum Surface Range (km)	Minimum Slant Range (km)	Maximum Surface Range (km)	Maximum Slant Range (km)	Minimum Elevation Angle (degrees)	Maximum Elevation Angle (degrees)
150	48	48	283.2	283.3	-5.39	-2.12
3000	48	48	435.0	435.2	-2.15	-1.24
10000	48	48	596.3	596.8	-2.15	6.31

3. The next step in building the radar model is to determine the actual beam pattern for the radar. In many cases the antenna for an Air Surveillance Radar will be built in such a way that its two-way beam pattern (i.e., the combined transmit and receive antenna gain patterns, or Gt(**θe**)+Gr(**θe**), where **θe** is the beam elevation angle wrt the horizontal) will approximately follow a cosec^2(**θe**) curve. The reason for this is that, with this form of beam pattern, the strength of the echo from a target with a constant altitude and a constant RCS will be relatively constant as it approaches the radar. Figure C.5 shows a theoretical two-way beam (gain) pattern for such a radar system. This pattern is probably similar to what would be seen in the Air Traffic Control (ATC) systems used by NAV Canada, otherwise known as RAMP radars (RAdar Modernization Program) or RYC-8405. This might be confirmed by comparing it to the actual beam pattern that can be extracted from the RADES database for the long range mode of the NAV Canada RYC-8405 ATC radar; however, for the purposes of this tutorial, we will assume that it is correct.

   Figure C.5 also shows how we can segment the beam pattern into multiple FOVe in order to more closely emulate the detection capability of the actual system for most of the system's elevation FOV. Each FOVe segment will be treated as a different "virtual" radar using the VIEE++ cloning tool, which will then feed a single tracker so that the combination acts like a single radar system with the combined FOV of all of the virtual subsystems (as shown in Figure 24).

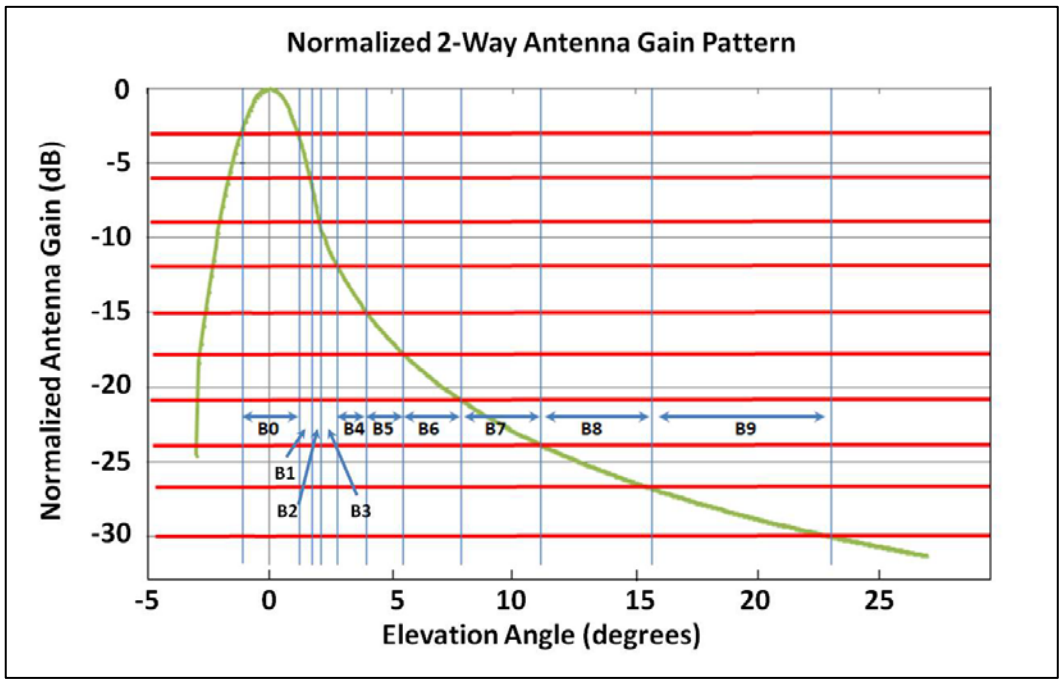


Figure C.5: *Screen capture for a theoretical 2-way cosec^2 beam pattern (2 x one-way for a monostatic radar) showing the range of location of some of the segmented FOVe. We will only do the beams above the main beam (B0), but you could go farther and include the low angle beams.*

   It turns out that most of the parameters that are needed for our RAMP radar simulation can be found in open sources, and are listed in Table C.2

Table C.2: *Radar specifications for the RYC-8405, RAMP radar system (from Skolnik, Industry Canada, and Jane's).*

Parameter	**Value**	
Carrier Frequency (MHz)	1250 – 1350	
Peak Power (kW)	25 (min)-28 (max) kW	
Azimuth Resolution (deg.)	2.25	
Range Resolution (nmi/km)	0.25/.463	
Duty Cycle	6.8%	
Detection Capability	Up to 80 nmi at 23000 ft (7010 m) with 80% probability of detection (Pd) against a target with a RCS of 2 m^2	
Waveforms (double pulse pair)	Short Range Mode (<8 nmi)	1 µs CW pulse
	Long Range Mode (≥8nmi)	100 µs non-linear chirp pulse
		Pulse compression ratio (PCR)=100:1
Signal Processing	4 pulse Moving Target Indicator (MTI)	
Antenna Gain (dB) (Tx or Rx)	33.5	
Antenna Height (m AGL)	24	

Based on the duty cycle specified in Table C.2, the number of pulses per second, (a.k.a. the pulse repetition rate, or PRF) is about 680 Hz. Using this value, we can estimate what the radar's instrumented range may be (often equal to what is referred to as the maximum unambiguous range, or Ru), which according to Equation (7), is approximately 221 km or 120 nmi.

$$\text{Ru}=\frac{\text{speed of light } (3\text{x}10^8 \text{ m/s})}{2 \cdot \text{PRF}} \approx 221 \text{ km} \approx 120 \text{ nmi} \tag{C.7}$$

Although it is difficult to find an internet reference for the rotation rate of the RAMP radar, it could reasonably be assumed that it would be similar to other Airport Surveillance Radar (ASR) systems, like the ASR-11 which (according to Jane's) has a rotation rate of 12 rpm (hence a scan period of 5 seconds). Industry Canada sources also state that the maximum antenna gain for this radar is about 33.5 dB.

If we assume that there is no pulse integration for the long range mode, then according to the **Neuvy_DetectabilityFactorCalculator** spreadsheet, the required SNR0 for an 80% Pd is 17.75 dB at the reference range of 150 km (80 nmi).

Therefore, we now know the values for the radar parameters that need to be inserted into the VIEE++ GUI for each virtual sensor. These values are listed in Table C.3.

Table C.3: *Beam parameters values for RAMP radar.*

	Beam Name									
Parameter Name	**B0**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**B9**
Min. El. Angle (deg.)	-1.18	+1.18	1.71	2.06	2.75	3.92	5.45	7.84	11.12	15.63
Max. El. Angle (deg.)	+1.18	1.71	2.06	2.75	3.92	5.45	7.84	11.12	15.63	23.06
El. Std (deg.)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Min. Az. Angle (deg.)	-180	-180	-180	-180	-180	-180	-180	-180	-180	-180
Max. Az. Angle (deg.)	180	180	180	180	180	180	180	180	180	180
Az. Std (deg.)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Min. Range (m)	15000	15000	15000	15000	15000	15000	15000	15000	15000	15000
Max. Range (km)	221	221	221	221	221	221	221	221	221	221
Range Std	230	230	230	230	230	230	230	230	230	230
Range0 (m)	150000	115769	97407	81958	68959	58022	48819	41076	34561	29080
Sigma0 (m^2)	2	2	2	2	2	2	2	2	2	2
SNR0 (dB)	17.75	17.75	17.75	17.75	17.75	17.75	17.75	17.75	17.75	17.75

Example 2—AESA Radar System:

The process to follow for this example of an Active Phased Array or Active Electronically Scanned Array (AESA) radar will be similar to the previous one, except that this time the AESA radar has been defined by the individual beams (in this case there are 6 elevation beams) as well as a so-called "composite" beam that one would suppose should be the envelope of the 6 individual beams. In this example, we will assume that the AESA radar has the specifications listed in Table C.2 and that the fictitious beam patterns are as shown in Figure C.6 and Figure C.7. Notice that the outline of the composite beam pattern of this fictitious AESA radar is very similar to the cosec^2 antenna pattern used in our previous example for our simulated RYC-8405 RAMP radar. Our model for the AESA array radar assumes that the radar antenna consists of a single planar array antenna face that can only scan electronically in the vertical (elevation) direction, and that in order to get a full or partial 3D perspective, it must rotate 360 degrees in azimuth (i.e., horizontally). Some typical examples of radar systems that fit this general description are the AN/FPS-117 (long range radar for the North Warning System), the AN/TPS-70 mobile long range air surveillance radar system, and SAAB's medium range Sea Giraffe AMB (Agile Multi-Beam) radar system. There are also many other similar systems around the world that fit this general description.

The parameters used for the fictitious AESA radar are found in Table C.4.

Table C.4: *Fictitious AESA radar specifications assumed for this example.*

Parameter	**Value**	
Carrier Frequency (MHz)	2900 – 3100	
Peak Power (kW)	100	
Azimuth Resolution (deg.)	2.25 (half of this value, 1.13 deg., is used for the Azimuth STD)	
Elevation angle STD (deg)	1.0	
Range Resolution (nmi/km)	0.08/0.15	
Duty Cycle	8%	
Waveforms (pulse pair)	Long Range Mode (≥30 km or 16 nmi)	Two contiguous 100 µs linear chirp pulses separated in frequency
		Pulse compression ratio (PCR)=100:1
Number of pulses non-coherently integrated	2	
Max Antenna Gain (dB) (Tx or Rx) for B1	40	
Max Antenna Gain (dB) (Tx or Rx) for B2	36.5	
Max Antenna Gain (dB) (Tx or Rx) for B3	33	
Max Antenna Gain (dB) (Tx or Rx) for B4	31.25	
Max Antenna Gain (dB) (Tx or Rx) for B5	39	
Max Antenna Gain (dB) (Tx or Rx) for B6	27.75	
System Noise Temperature (˚K)	450	
Combined Losses (dB)	6	
SNR0 (dB)	10.38 (for Pd=0.5, Pfa=1e-6, nnc=2, Swerling 1 target)	
Antenna Height (m AGL)	24	

Based on some of the values provided in Table C.4 the minimum range for the long range mode will be 30 km (i.e., speed of light multiplied by half the overall pulse length of 200 µs) and the maximum instrumented range will be 400 km based on the duty cycle with the range uncertainty estimated to be half of the compressed pulse length of 1 µs, or 150 m. Also, using the values provided in the table, the reference range (R0 or Range0) for the lowest elevation beam angle (B1) is found, using the **Reference_Range_Calculator.xls** spreadsheet to be 391.4 km and each subsequent R0 value is calculated using the spreadsheet by subtracting the appropriate difference in maximum antenna gain inferred from Table C.4 The latitude and longitude of the individual "virtual" sensors, and the final composite sensor can be chosen to be in the La Malbaie area at a height relative to ground level of 20 m, and a geographic location of 47.6284°N and 70.1659°W.

Figure C.8 and Figure C.9 show how the beam segmentation is ultimately decided. Table C.5 and Table C.**6** list the upper and lower limits of each beam segment along with their respective R0 values that are associated with their respective figure. Construction of the radar model using the VIEE++ GUI will look very similar to that shown in Figure 24 but will only have 6 virtual radar sensors feeding the tracker module.

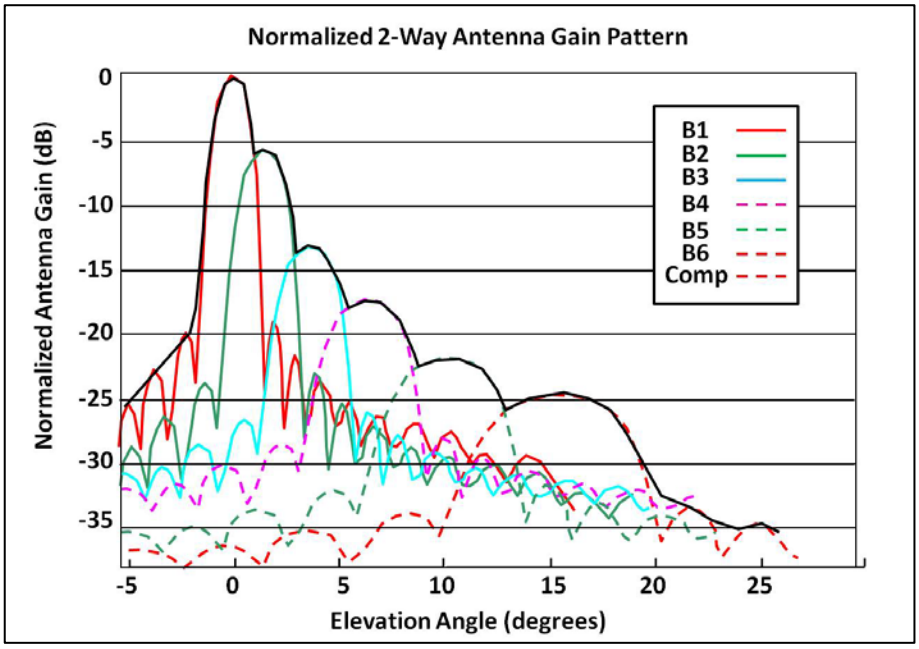


Figure C.6: *Normalized beam patterns for beams B1 through B6, and the composite (Comp) beam envelope.*

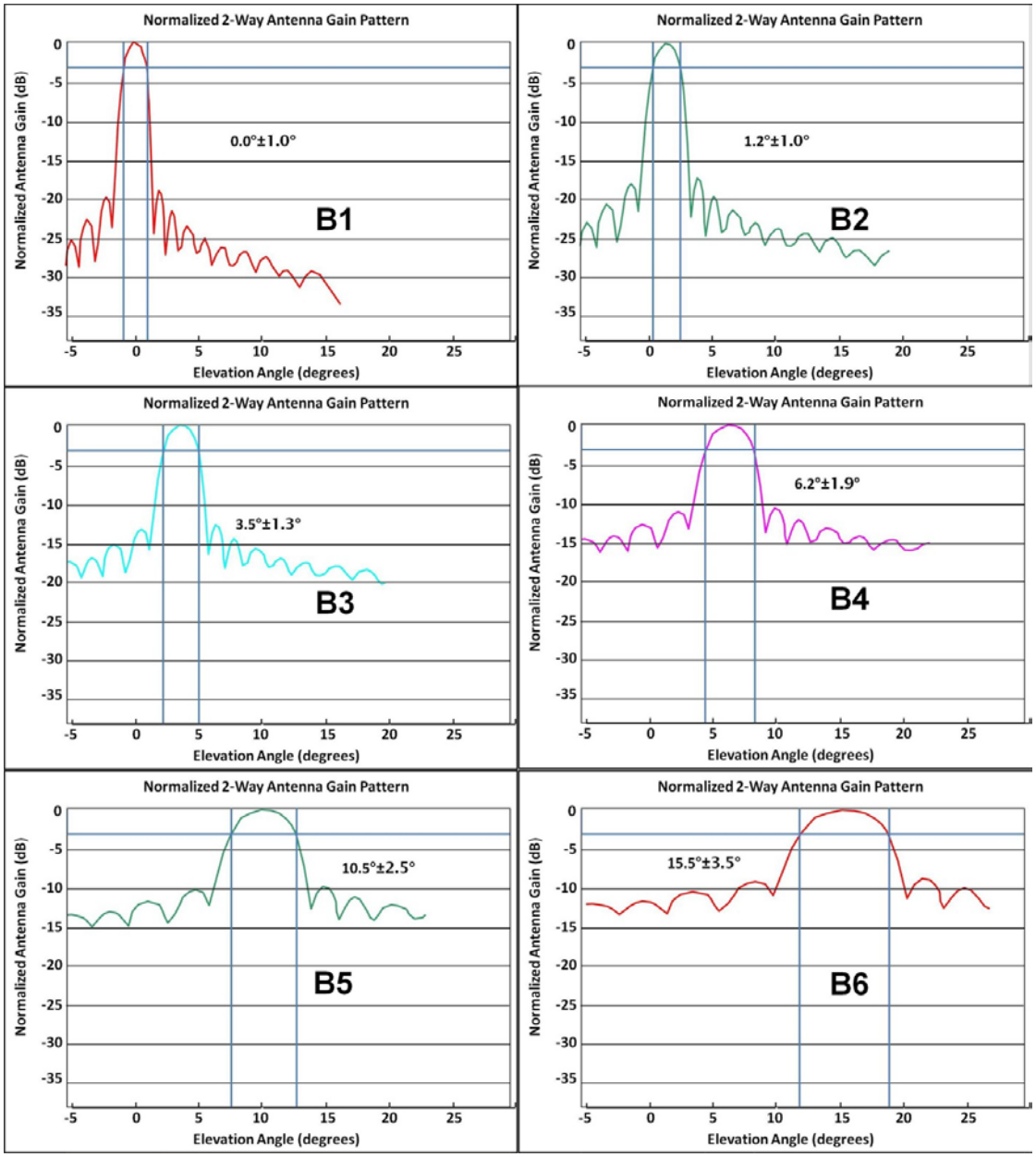


Figure C.7: *All six beams of the AESA radar, individually normalized to 0 dB, and showing the -3 dB beamwidth for each beam. The individual beam limits are listed in Table C.5 along with the R0 values for each beam.*

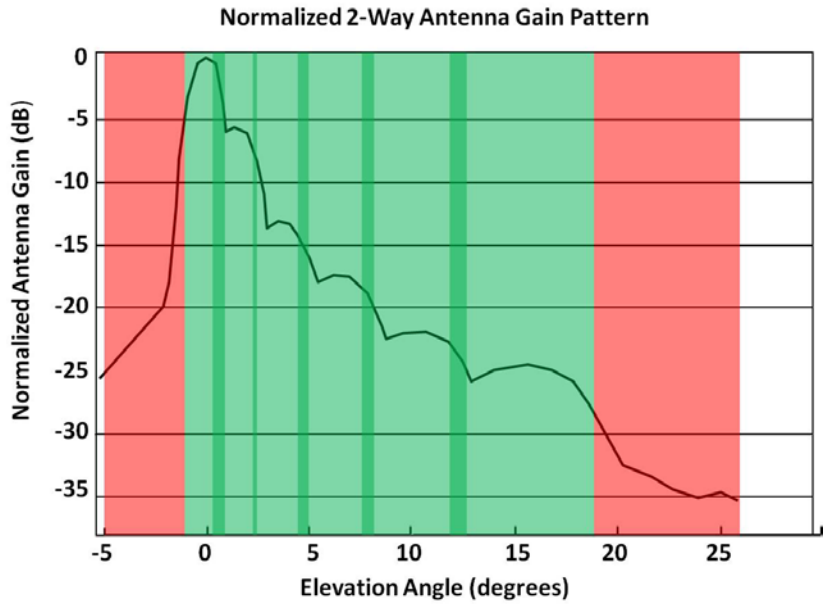


Figure C.8: *Composite AESA beam pattern showing where the individual -3 dB beams are located (shaded light green), where adjacent beams overlap (shaded dark green), or (shaded red) where there is no coverage.*

Table C.5: *AESA individual beam limits along with the R0 values.*

Beam Name	Lower Limit	Upper Limit	R0 value (m)
B1	-1.0	1.0	391400
B2	0.2	2.2	262000
B3	2.2	4.8	175000
B4	4.3	8.1	143000
B5	8.0	13.0	110000
B6	12.0	19	95500

To partially remedy the situation shown in Figure C.8 and Table C.5, some slight modification of the adjacent limits may be in order, resulting in the results shown in Figure C.9 and listed in Table C.6.

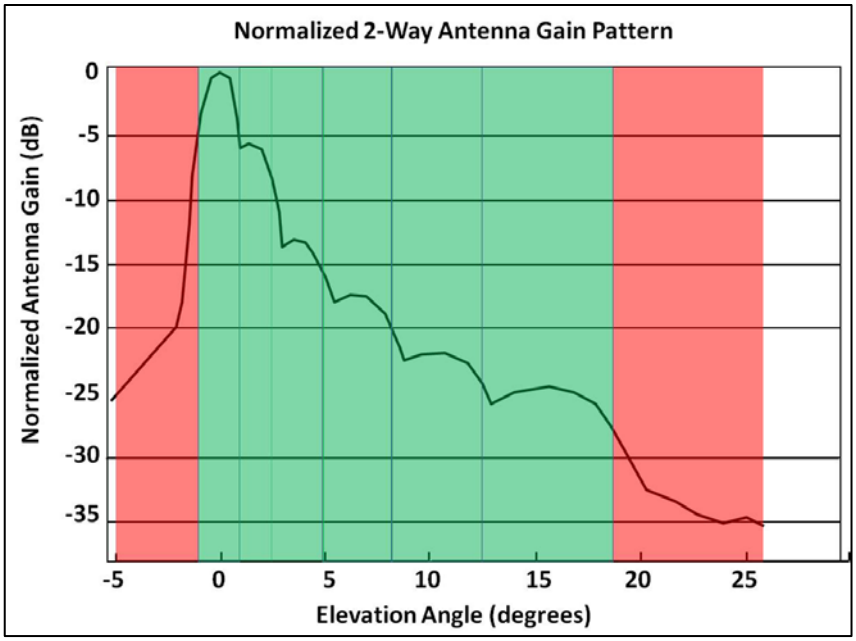


Figure C.9: *Composite AESA beam pattern showing the new limits for the FOVe of each contiguous "virtual beam" (shaded green, and limits by blue lines) with two remaining gaps at the two elevation extremes. This avoids double counting of measurements that might occur with overlapping FOVe.*

Table C.6: *Slight modification of individual beam limits along with the R0 values.*

Beam Name	Lower Limit	Upper Limit	R0 value (m)
B1	-1.0	1.0	391400
B2	1.0	2.2	262000
B3	2.2	4.8	175000
B4	4.8	8.1	143000
B5	8.1	13.0	110000
B6	13.0	19	95500

Figure C.10 shows a screen capture of the **Reference_Range_Calculator.xlsx** for this example.

	A	B	C	D	E	F	G	H	I	J	K
1											
2		Peak Power (kW)	Pulse Width (microsec)	Receiver Gain(dB)	Transmitter Gain (dB)	Frequency (MHz)	RCS (sqm)	-SNR0 (dB)	System Temperature (deg. K)	Total Loss Factors(dB)	Lumped constants
3	value in given units	100	100	40	40	3000	1	-10.39	450	-6	3.65167E+19
4	relevant value converted to dB	50	-40	40	40	-20	1	-10.39	-26.53212514	-6	195.6249132
5	total	223.7027881									
6	Reference Range R0	391353.9323									
7	If R0 given, doesn't need calc.	Enter value for R0	391354								
8		Reference Range R1	302043.6968	down 4.5 dB		97407.24474					
9		Reference Range R2	254138.099	down 7.5 dB		81957.98248					
10		Reference Range R3	213830.5618	down 10.5 dB		68959.04828					
11		Reference Range R4	179915.9959	down 13.5 dB		58021.80819					
12		Reference Range R5	151380.4448	down 16.5 dB		48819.26752					
13		Reference Range R6	127370.7708	down 19.5 dB		41076.29451					
14		Reference Range R7	107169.1478	down 22.5 dB		34561.39464					
15		Reference Range R8	90171.60026	down 25.5 dB		29079.78954					
16		Reference Range R9	75869.94637	down 28.5 dB							
17											
18		Gain Reduction (dB)	R0 (m)	RN(m)							
19	Adjusted **R0** (i.e. **RN**) for arbitrary gain reduction	24.5	391354	95514.60348							

Figure C.10: *Screen capture of the Reference_Range_Calculator spreadsheet with some of the numbers used to generate R0 for this example; the values for R1 to R9 do not apply in this case.*

Radar Equation:

$$R0=\left[\frac{P_t \tau G_t G_r \lambda^2 \sigma}{(4\pi)^3 (kT_s)(SNR0) L_t}\right]^{1/4}$$

Where:

G_t= *Transmitter antenna gain*

G_r = *Receiver antenna gain*

P_t = *Peak transmitted power (W)*

τ= *radar signal pulse length (s)*

λ = *radar signal wavelength (m)*

T_s = *Effective system temperature (°K)*

L_t = *sum of all loss terms*

k= Boltzmann's constant=$1.38064852 \times 10^{-23}\ m^2\ kg\ s^{-2}\ K^{-1}$

R0=reference range (m)

SNR0= reference (minimum) signal-to-noise-ratio

σ= *target radar cross section (RCS)* (m^2)

List of Symbols/Abbreviations/Acronyms/Initialisms

1 CAD	1 Canadian Air Division
ADS-B	Automatic Dependent Surveillance-Broadcast
AEE	Average Euclidean Error
AESA	Active Electronically Scanned Array
AGE	Average Geometric Error
AGL	Above Ground Level
AHE	Average Harmonic Error
AIS	Automatic Identification System
AMB	Agile Multi-Beam
AOI	Area of Interest
ASL	Above Sea Level
ASR	Airport Surveillance Radar
ATC	Air Traffic Control
DDS	Data Distribution Service
DND	Department of National Defence
DRDC	Defence Research and Development Canada
DSTKIM	Director Science and Technology Knowledge and Information Management
DTED	Digital Terrain Elevation Data
EO/IR	Electro-Optical/Infrared
FOV	Field of View
GPS	Global Positioning System
GUI	Graphical User Interface
IMM	Interacting Multiple Model
ISR	Intelligence Surveillance Reconnaissance
JIPDA	Joint Integrated Probabilistic Data Association
JLENS	Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System
JPDA	Joint Probability Data Association
LOS	Line of sight
MFA	Multiple Frame Association
MHT	Multi Hypothesis Tracking

MOE	Measures of Effectiveness
MOP	Measures of Performance
MPAR	Multi-function Phased Array Radar
MSL	Mean Sea Level
MTI	Moving Target Indicator
MTT	Multiple Target Tracking
NWS	North Warning System
Pd	Probability of Detection
RADES	Radar Evaluation Squadron
RAMP	Radar Modernization Project
RCS	Radar Cross Section
RMSE	Root Mean Squared Error
SNR	Signal to Noise Ratio
TARS	Tethered Aerostat Radar System
UAV	Unmanned Aerial Vehicle
VIEE++	Virtual ISR Evaluation Environment++

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13. ABSTRACT (When available in the document, the French version of the abstract must be included here.)

This Defence Research and Development Canada (DRDC) – Ottawa Research Centre Reference Document is a training manual that was used in training operators, officers, and planners at 1 Canadian Air Division (1 CAD) in Winnipeg in March 2018. The training was based on a software called Virtual Intelligence, Surveillance and Renaissance (ISR) Evaluation Environment (VIEE++) which is a custom licensed version of Trackgen Solutions Inc. ISR360 product. VIEE++ is an ISR evaluation environment that allows for multi-sensor multi-domain scenario generation and analysis of surface, sub-surface, air, land and space targets/platforms. Radar measurement generation, tracking and data fusion are modelled in this unified framework. The purpose of the training session was to present how DRDC – Ottawa Research Centre uses VIEE++ and how it could be applied to 1 CAD operational mission planning. Given time constraints, not all features of the application were presented during the training session.

Le présent document de référence, élaboré par le Centre de recherches d'Ottawa de RDDC, est un manuel de formation ayant servi à l'apprentissage des opérateurs, des officiers et des planificateurs de la 1ère Division aérienne du Canada (1 DAC) à Winnipeg en mars 2018. La formation portait sur un logiciel appelé Virtual ISR Evaluation Environment (VIEE++), une version personnalisée du produit ISR360 de Trackgen Solutions Inc. sous licence d'exploitation. VIEE++ fournit un environnement pour l'évaluation du renseignement, de la surveillance et de la reconnaissance (RSR). Plus précisément, il permet de générer des scénarios multicapteurs et multidomaines, et d'analyser les plateformes ou les cibles de surface, sous-marines, aériennes, terrestres ou spatiales. La génération de mesures de signaux radar, la localisation et la fusion de données sont modélisées dans ce cadre unifié. Le but de la séance de formation était d'expliquer comment le Centre de recherches d'Ottawa utilise VIEE++ et d'énumérer les possibilités d'application par la 1ère Division aérienne du Canada dans la planification des missions opérationnelles. Vu les contraintes de temps, les caractéristiques du logiciel n'ont pas toutes été abordées pendant la séance de formation.