

# FIR MVP Requirements

## Version History

Version Number	Date	Description
4.1	10/15/2020	New numbered formatting, removed table of contents, created a notes section at the end of the document
4.2	10/23/2020	Added details on AR output, HMI formatting Updated boundary diagram Added information about FIR image output
4.3	11/20/2020	Expanded on camera decision logic to use rolling short and long term histories of values Added default values with configurable items for future engineering experimentation
4.3.24 (Working)	12/4/2020	Removed Failure Mode section. See DFMEA for management. Updates to visible camera parameter history gathering Updated decision logic to include robustness actions
4.4	5/18/2021	Updated with Final MVP results
5.0	8/18/2021	Updated document to remove FIR-only HMI option Updated FIR cropping language

# FIR MVP Requirements

## 1. Feature Overview

1.1. This feature presents an Augmented Reality (AR) view of the road ahead using the video data from a Far Infrared (FIR) camera as a background. The FIR camera creates images from objects generating thermal energy. For night and dark conditions, this camera can create a night vision view of the road ahead when the standard visible AR camera cannot fully meet customer expectations. While the FIR background will appear as a black and white image to the driver, the AR elements that overlay the background shall be in full color.

## 1.2. Key Modules Involved

1.2.1. Augmented Reality ECU (AR ECU)

1.2.2. APIM (Sync)

## 1.3. Interfaces

1.3.1. High Heads Down Display (HHDD)

## 1.4. Key Sensors

1.4.1. FIR camera

1.4.2. Visible augmented reality camera (AR camera)

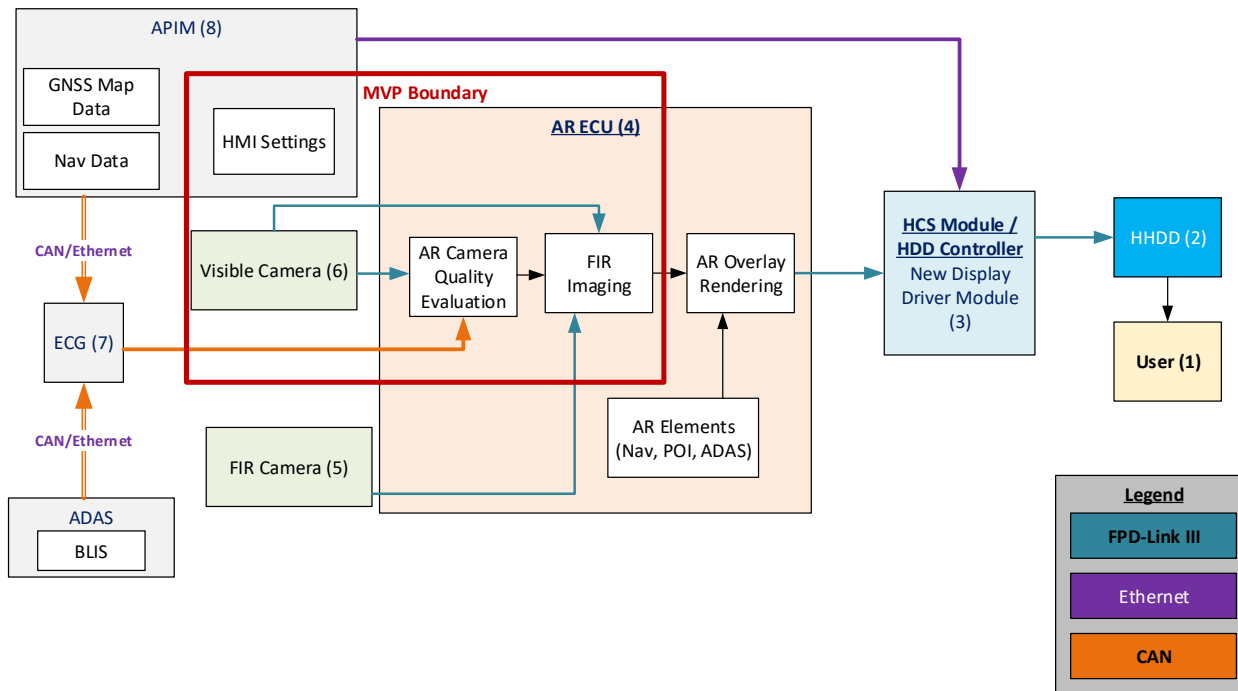


Figure: Boundary Diagram

## 2. ECU Functionality

### 2.1. AR ECU

#### 2.1.1. Inputs

##### 2.1.1.1. AR Camera

###### 2.1.1.1.1. Interface

Input: FPD-Link III, into AR ECU

###### 2.1.1.1.2. Data

The FIR camera shall be able to transmit the following information over the I2C backchannel up to 60 Hz

###### 2.1.1.1.2.1. Camera Gain

Shall transmit camera gain information to the AR ECU

###### 2.1.1.1.2.2. Camera Integration Time

Shall transmit integration time information to the AR ECU

#### 2.1.1.2. FIR Camera

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## 2.1.1.2.1. Input

FPD-Link III, into AR ECU

## 2.1.1.2.2. End-of-Line Configuration

The FIR camera view is an optional item for the Augmented Reality feature. If the FIR camera is installed on the vehicle the FIR camera shall be selectable via End-of-Line.

## 2.1.1.2.3. Packaging

### 2.1.1.2.3.1. Camera Orientation

The FIR camera must be oriented so that:

#### 2.1.1.2.3.1.1.

The centroid of both AR and FIR camera images shall be within **10** pixels of each other after FIR image resized (grid-like target)

#### 2.1.1.2.3.1.2.

The horizon line matches between FIR & AR cameras within **10** pixels after FIR image resized

## 2.1.2. Outputs

### 2.1.2.1. Camera Selection/View for Augmented Reality

An “augmented reality event” is a time when the user sees augmented reality elements overlaid on a visible (or AR) camera window shown on the display. The intent is to use the AR camera as the background during the daytime (bright conditions), and the FIR camera as the background at nighttime (dark conditions). To do this, the automatically-adjusted parameters of the AR camera (e.g., gain, integration time) are used to gauge the image quality.

Using the known values for gain and integration time, the system can identify when the FIR camera background will be a better choice for the night condition instead of the AR camera. If these values cross the set threshold during an AR event, the camera background will not change (i.e., do not switch camera backgrounds in the middle of an AR event).

#### 2.1.2.1.1.

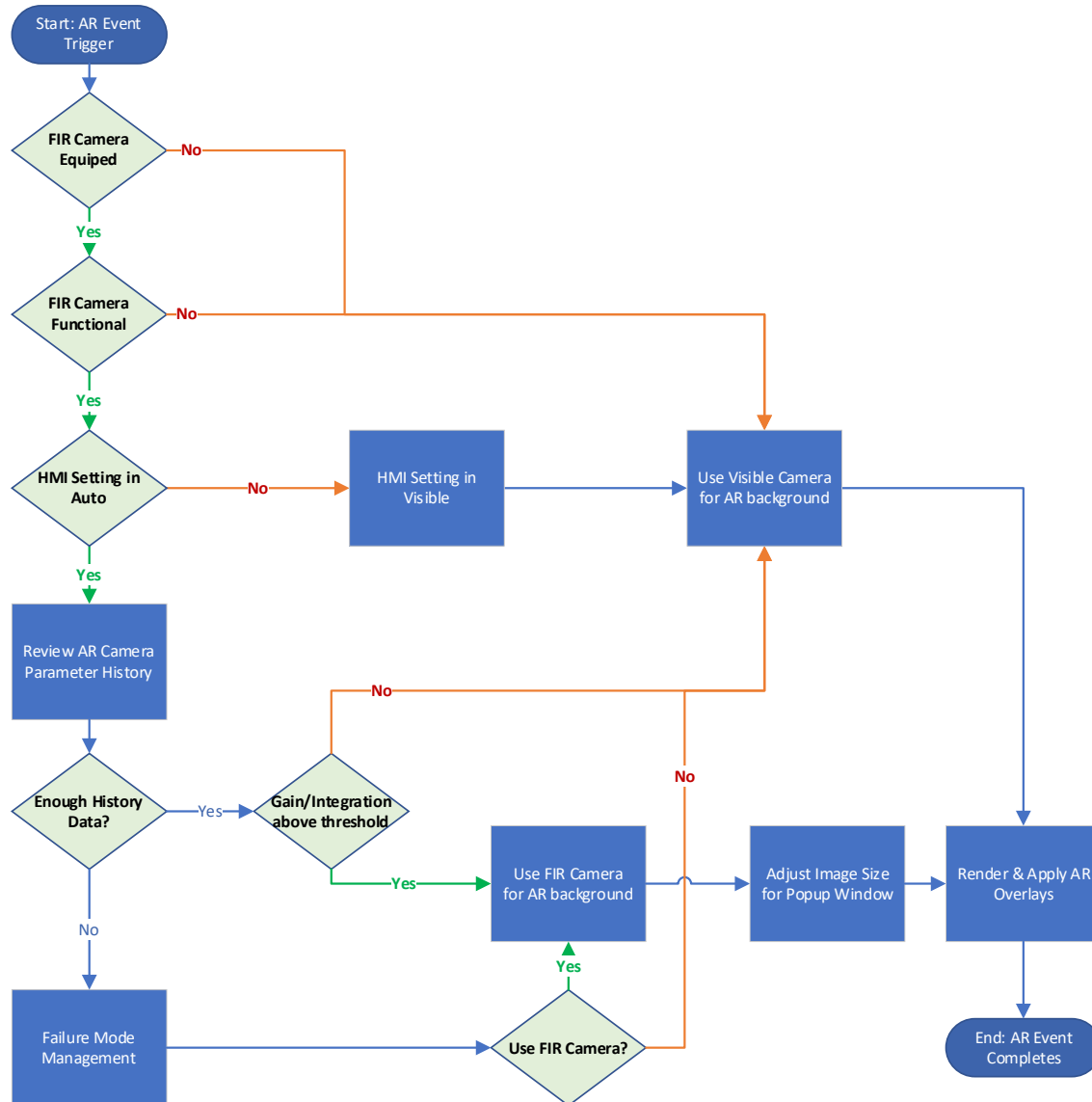
The appropriate camera background of this view shall be based on the gain and integration time of the AR camera as well as the user’s chosen AR settings.

#### 2.1.2.1.2.

This view shall be resized accordingly to fit the AR HMI.

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## 2.1.3. Action



### 2.1.3.1. Initial Checks

2.1.3.1.1. When the system recognizes a signal for the need to show an AR event on screen, the system shall first check if the following are true:

#### 2.1.3.1.1.1.

The system shall verify that the vehicle is equipped and configured to use the FIR camera

#### 2.1.3.1.1.2.

The system shall verify that the FIR camera is functioning

#### 2.1.3.1.1.3.

The system shall verify that the user has set the AR camera selection setting to Automatic

#### 2.1.3.1.1.4.

If any of these requirements are not met, then the standard visible AR camera shall be used instead.

### 2.1.3.2. Decision to Use FIR Camera

#### 2.1.3.2.1. Decision Parameters

If the previously mentioned requirements are all met, the system shall determine which camera to use based on the following values.

##### 2.1.3.2.1.1. AR camera's gain

##### 2.1.3.2.1.2. AR camera's integration time

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## 2.1.3.2.1.3. Time of Day

This information is already provided to the AR ECU for navigation use cases

## 2.1.3.2.1.4. Vehicle Heading Information

This information is already provided to the AR ECU for navigation use cases

## 2.1.3.2.2. History of Camera Frame Parameters

A rolling history of the AR camera parameters shall be stored over the course of the drive. This history is used to mitigate noise.

### 2.1.3.2.2.1. Short Term Frame Parameter History

The AR ECU shall hold a rolling memory of camera parameters from the last **60 frames** over the past **60 seconds** from before the AR event trigger has been received. These values are recorded at a periodic rate of **1 Hz / frame per second**.

2.1.3.2.2.1.1. The periodic sampling rate shall be configurable between 1 Hz and 60 Hz

2.1.3.2.2.1.2. The number of sets of frame parameters to save in the short term parameter history shall be configurable between 1 and 500.

2.1.3.2.2.1.3. The time window for the short term frame parameter history shall be configurable between 1 second and 120 seconds.

2.1.3.2.2.1.3.1. The maximum time window shall be limited by the rate of sampling for the camera parameters and the number of stored sets of frame parameters

### 2.1.3.2.2.2. Long Term Frame Parameter History

The AR ECU shall hold a rolling memory of camera parameters from the last **60 frames** over the past **5 minutes** previous to the short term parameter history. These values are recorded at a periodic rate of **0.2 Hz / frame per second (or 12 frames per minute)**.

2.1.3.2.2.2.1. The periodic sampling rate shall be configurable between 0.01667 Hz (1 frame per minute) and 60 Hz

2.1.3.2.2.2.2. The number of sets of frame parameters to save in the short term parameter history shall be configurable between 1 and 500

2.1.3.2.2.2.3. The time window for the long term frame parameter history shall be configurable between 5 minutes and 10 minutes.

2.1.3.2.2.2.3.1. The maximum time window shall be limited by the rate of sampling for the camera parameters and the number of stored sets of frame parameters

### 2.1.3.2.2.3. Camera Parameter History Retention

After key off, the AR ECU shall clear the short term history. The AR ECU shall clear the long term history after **6 minutes**.

2.1.3.2.2.3.1. The time to clear the long-term history shall be configurable between 1 and 15 minutes.

## 2.1.3.2.3. Decision Logic

If the values for the gain and integration time are equal to or below the set thresholds that correlate to the SNR value reduction from optimal of **15% from optimal** dB with a tolerance of **+/- 5% from optimal** dB, then the FIR camera shall be selected as the background for the AR event. If these values are above the set thresholds, then the standard visible AR camera shall be used instead.

The values used for this decision are based on one of the following situations below.

### 2.1.3.2.3.1. Situation 1: Full Parameter History Log

The values for gain and integration time shall be chosen based on the average values over the short term history. If these values are greater or smaller compared to the average value over the long term history by **[tolerance range(s)]**, then the average between the long term and short term averages shall be used as the final decision values.

### 2.1.3.2.3.2. Situation 2: Partially Filled Parameter History Log

The AR ECU shall choose the camera for AR as in Situation 1 but with a limited decision set.

2.1.3.2.3.2.1. If the camera parameters indicate that the AR camera would be chosen, but the previous camera choice was the FIR camera, then the FIR camera shall be used for the AR event

### 2.1.3.2.3.3. Situation 3: Empty Long Term History Log with Partial/Full Short Term History

The values for gain and integration time shall be chosen based on the average values over the short term history.

2.1.3.2.3.4. If the AR camera is chosen, the system shall check to make sure that the vehicle is not driving into the sun using the time of day and GPS bearing

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2.1.3.2.3.4.1. If the vehicle is driving East, North East, or South East between **6:00AM** and **9:00AM** in the morning, then the FIR camera shall be chosen for AR events

2.1.3.2.3.4.1.1. The beginning and end times for this time window shall be configurable between 5:00AM and 10:00AM

2.1.3.2.3.4.2. If the vehicle is driving West, North West, or South West between **6:00PM** and **9:00PM** in the evening, then the FIR camera shall be chosen for AR events

2.1.3.2.3.4.2.1. The beginning and end times for this time window shall be configurable between 5:00PM and 10:00PM

2.1.3.2.4. Decision Timing

The camera background choice shall be made within 50 ms, of the trigger for an AR event (timing should match AR camera).

2.1.3.2.5.

The AR view with an FIR background shall appear when an AR event must be shown and shall disappear from the display when all AR events end.

## 2.1.3.3. FIR AR Presentation

2.1.3.3.1.

The chosen camera for the AR background shall not change during an already occurring AR event that is being presented to the driver.

2.1.3.3.2.

With respect to FIR camera images, “Black hot” images are images that present hotter elements in as darker. “White hot” images are those that show hotter elements as brighter.

The FIR camera view background shall be set to **black hot**.

2.1.3.3.2.1. For engineering purposes, the AR ECU shall be configurable with the ability to switch the camera view between white hot and black hot. This capability is not needed as an End-of-Line parameter.

2.1.3.3.3. FIR Image Manipulation

The FIR image shall be cropped and then upsampled as described below.

2.1.3.3.3.1. Cropping from the bottom of the image shall be configurable between a configurable 0 to 200 rows of pixels

2.1.3.3.3.1.1. The amount of cropping shall be determined, in conjunction with, and approved by a Ford D&R based on target vehicle mounting.

2.1.3.3.3.2. The amount of cropping from the top of the image shall be configurable between 0 and 200 pixels.

2.1.3.3.3.2.1. The amount of cropping shall be determined, in conjunction with, and approved by a Ford D&R based on target vehicle mounting.

2.1.3.3.3.3. The cropped FIR image shall be upsampled so that the new increased height matches the AR window

## 2.1.3.3.4. Human Machine Interface

Currently, AR events are planned to be shown in a pop-up window in the HHDD display UI. This window only appears during AR events and disappears on completion of the event. The AR events that use the FIR background shall also use this same behavior with the following differences.

2.1.3.3.4.1.

The FIR image shall be resized to appropriately fit the AR pop-up UI while maintaining the aspect ratio

2.1.3.3.4.2.

The FIR image shall be centered in the AR pop-up UI

2.1.3.3.4.3.

Supplier shall work with Ford to design an HMI for the transition between the FIR and visible camera backgrounds and the appearance of the FIR window.

## 2.1.3.3.5. AR Overlay Reshaping

2.1.3.3.5.1.

The AR system shall accommodate the differences in camera perspective, resolution, field of view, and aspect ratio when rendering AR overlays onto the FIR camera background view.

2.1.3.3.5.2.

The AR overlays shall be applied to the resized FIR image

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## 2.1.3.3.5.3.

The AR elements shall remain within the field of view of the FIR camera image

## 2.2. APIM ECU

### 2.2.1. HMI Settings

#### 2.2.1.1.

If a vehicle is equipped with both a visible and an FIR camera, there shall be an HMI setting in the AR settings menu that allows the user to choose their preference for what AR camera is shown on screen.

2.2.2. The AR camera selection setting options shall include the following:

#### 2.2.2.1. Automatic (Default):

The system shall choose which camera to use for the background of the AR events based on the AR camera data

#### 2.2.2.2. Disable:

2.2.2.2.1. This setting shall disable the FIR camera from being used as the AR background and force it to be the Augmented reality visible camera.

## Notes

### SNR & Relation to Gain/Integration Time

The gain and integration time will be used by the final system to determine when the FIR camera should be used as the background of the next AR event. The proper thresholds for these two camera values are specific to the camera model used.

A calculated optimal SNR value for the given Augmented reality camera for each individual program shall be calculated by testing the SNR of the camera in a laboratory environment. The appropriate gain value to transition to the FIR camera shall be defined as the point at which the SNR value of the Augmented reality camera is reduced by 15% from optimal (+/- 5%).

For a specific camera, the gain and integration time are derived from this SNR value. These values shall be used for the threshold to determine when to use the FIR camera shall be made. The method for deriving these shall be part of a separate document.

### FIR Images: Black Hot & White Hot

With respect to FIR camera images, “Black hot” images are images that present hotter elements in the as darker. “White hot” images are those that show hotter elements as brighter.

## Extensions

The following item may be considered for extending or altering the behavior of the FIR-AR mode.

Hysteresis: If the time between AR events is small enough, continue using the FIR camera if it was used in the last AR event

### Dependencies for AR Use Cases on the ADAS Camera

Some AR overlays are dependent on the ADAS camera to accurately render content on the road. This is achievable with the visible camera background because of the distance between these two camera views is small enough to properly map lane data from the ADAS camera to the AR camera. To achieve this same effect with an FIR camera background, the FIR camera must be close enough to the ADAS camera.

If this is not possible, alternatives must be considered for use cases that require accuracy to overlay data on the road ahead. Special consideration must be made for these to avoid confusion the driver with unexpectedly different use case behaviors at night.