

**Provisional Application for Patent Cover Sheet**

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c)

**Inventor(s)**

Inventor 1

| Given Name | Middle Name | Family Name | City          | State | Country |
|------------|-------------|-------------|---------------|-------|---------|
| Nicholas   |             | Högasten    | Santa Barbara | CA    | US      |

All Inventors Must Be Listed – Additional Inventor Information blocks may be generated within this form by selecting the **Add** button.

|                           |                                |
|---------------------------|--------------------------------|
| <b>Title of Invention</b> | VEHICLE BASED RADAR UPSAMPLING |
|---------------------------|--------------------------------|

|                                        |                |
|----------------------------------------|----------------|
| Attorney Docket Number (if applicable) | 70052.1418US01 |
|----------------------------------------|----------------|

**Correspondence Address**

Direct all correspondence to (select one):

|                                                                               |                                               |
|-------------------------------------------------------------------------------|-----------------------------------------------|
| <input checked="" type="radio"/> The address corresponding to Customer Number | <input type="radio"/> Firm or Individual Name |
|-------------------------------------------------------------------------------|-----------------------------------------------|

|                 |       |
|-----------------|-------|
| Customer Number | 85112 |
|-----------------|-------|

|                                                                                                                                         |
|-----------------------------------------------------------------------------------------------------------------------------------------|
| The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government. |
|-----------------------------------------------------------------------------------------------------------------------------------------|

|                                      |
|--------------------------------------|
| <input checked="" type="radio"/> No. |
|--------------------------------------|

|                                                                                                                                     |
|-------------------------------------------------------------------------------------------------------------------------------------|
| <input type="radio"/> Yes, the invention was made by an agency of the United States Government. The U.S. Government agency name is: |
|-------------------------------------------------------------------------------------------------------------------------------------|

|                                                                                                                                                                                          |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="radio"/> Yes, the invention was under a contract with an agency of the United States Government. The name of the U.S. Government agency and Government contract number are: |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Entity Status****Applicant asserts small entity status under 37 CFR 1.27 or applicant certifies micro entity status under 37 CFR 1.29**

- ☐ Applicant asserts small entity status under 37 CFR 1.27
- ☐ Applicant certifies micro entity status under 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent.
- ☒ No

**Warning**

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

**Signature**

Please see 37 CFR 1.4(d) for the form of the signature.

|            |                                                                                     |           |     |                                      |            |
|------------|-------------------------------------------------------------------------------------|-----------|-----|--------------------------------------|------------|
| Signature  |  |           |     | Date (YYYY-MM-DD)                    | 2016-01-11 |
| First Name | Liyan                                                                               | Last Name | Zhu | Registration Number (If appropriate) | 71580      |

This collection of information is required by 37 CFR 1.51. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **This form can only be used when in conjunction with EFS-Web. If this form is mailed to the USPTO, it may cause delays in handling the provisional application.**

## Privacy Act Statement

**The Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that : (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                |                        |                |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|------------------------|----------------|
| <b>Application Data Sheet 37 CFR 1.76</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                | Attorney Docket Number | 70052.1418US01 |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                | Application Number     |                |
| Title of Invention                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | VEHICLE BASED RADAR UPSAMPLING |                        |                |
| <p>The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.</p> <p>This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.</p> |                                |                        |                |

**Secrecy Order 37 CFR 5.2:**

|                          |                                                                                                                                                                                                                                       |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <input type="checkbox"/> | Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.) |
|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Inventor Information:**

|                                                                                                                                                                          |               |                    |             |                      |        |     |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|--------------------|-------------|----------------------|--------|-----|
| Inventor 1                                                                                                                                                               |               |                    |             |                      | Remove |     |
| Legal Name                                                                                                                                                               |               |                    |             |                      |        |     |
| Prefix                                                                                                                                                                   | Given Name    | Middle Name        | Family Name | Suffix               |        |     |
|                                                                                                                                                                          | Nicholas      |                    | Högasten    |                      |        |     |
| Residence Information (Select One) <input checked="" type="radio"/> US Residency <input type="radio"/> Non US Residency <input type="radio"/> Active US Military Service |               |                    |             |                      |        |     |
| City                                                                                                                                                                     | Santa Barbara | State/Province     | CA          | Country of Residence | US     |     |
| Mailing Address of Inventor:                                                                                                                                             |               |                    |             |                      |        |     |
| Address 1                                                                                                                                                                |               | 70 Castilian Drive |             |                      |        |     |
| Address 2                                                                                                                                                                |               |                    |             |                      |        |     |
| City                                                                                                                                                                     | Goleta        | State/Province     | CA          |                      |        |     |
| Postal Code                                                                                                                                                              | 93117         | Country            | US          |                      |        |     |
| All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.                                     |               |                    |             |                      |        | Add |

**Correspondence Information:**

|                                                                                                                                       |                             |                           |
|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|---------------------------|
| Enter either Customer Number or complete the Correspondence Information section below.<br>For further information see 37 CFR 1.33(a). |                             |                           |
| <input type="checkbox"/> An Address is being provided for the correspondence information of this application.                         |                             |                           |
| Customer Number                                                                                                                       | 85112                       |                           |
| Email Address                                                                                                                         | ipdocketing@haynesboone.com | Add Email<br>Remove Email |

**Application Information:**

|                                         |                                |                                                      |  |
|-----------------------------------------|--------------------------------|------------------------------------------------------|--|
| Title of the Invention                  | VEHICLE BASED RADAR UPSAMPLING |                                                      |  |
| Attorney Docket Number                  | 70052.1418US01                 | Small Entity Status Claimed <input type="checkbox"/> |  |
| Application Type                        | Provisional                    |                                                      |  |
| Subject Matter                          | Utility                        |                                                      |  |
| Total Number of Drawing Sheets (if any) | 5                              | Suggested Figure for Publication (if any)            |  |

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

|                                           |                                |                        |                |
|-------------------------------------------|--------------------------------|------------------------|----------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                | Attorney Docket Number | 70052.1418US01 |
|                                           |                                | Application Number     |                |
| Title of Invention                        | VEHICLE BASED RADAR UPSAMPLING |                        |                |

**Filing By Reference:**

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

|                                                        |                          |                                            |
|--------------------------------------------------------|--------------------------|--------------------------------------------|
| Application number of the previously filed application | Filing date (YYYY-MM-DD) | Intellectual Property Authority or Country |
|                                                        |                          |                                            |

**Publication Information:**

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

**Representative Information:**

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

|                    |                                                  |                                              |                                                         |
|--------------------|--------------------------------------------------|----------------------------------------------|---------------------------------------------------------|
| Please Select One: | <input checked="" type="radio"/> Customer Number | <input type="radio"/> US Patent Practitioner | <input type="radio"/> Limited Recognition (37 CFR 11.9) |
| Customer Number    | 85112                                            |                                              |                                                         |

**Domestic Benefit/National Stage Information:**

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

|                          |                 |                          |                                    |
|--------------------------|-----------------|--------------------------|------------------------------------|
| Prior Application Status |                 | <a href="#">Remove</a>   |                                    |
| Application Number       | Continuity Type | Prior Application Number | Filing or 371(c) Date (YYYY-MM-DD) |
|                          |                 |                          |                                    |

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

|                                           |                                |                        |                |
|-------------------------------------------|--------------------------------|------------------------|----------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                | Attorney Docket Number | 70052.1418US01 |
|                                           |                                | Application Number     |                |
| Title of Invention                        | VEHICLE BASED RADAR UPSAMPLING |                        |                |

### Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)<sup>i</sup> the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

| Application Number | Country <sup>i</sup> | Filing Date (YYYY-MM-DD) | Access Code <sup>i</sup> (if applicable) | Remove |
|--------------------|----------------------|--------------------------|------------------------------------------|--------|
|                    |                      |                          |                                          |        |

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

### Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.

NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

|                                           |                                |                        |                |
|-------------------------------------------|--------------------------------|------------------------|----------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                | Attorney Docket Number | 70052.1418US01 |
|                                           |                                | Application Number     |                |
| Title of Invention                        | VEHICLE BASED RADAR UPSAMPLING |                        |                |

## Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

**NOTE:** This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

### 1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

**A. Priority Document Exchange (PDX)** - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

**B. Search Results from U.S. Application to EPO** - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

### 2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐ B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

**NOTE:** Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

|                                           |                                |                        |                |
|-------------------------------------------|--------------------------------|------------------------|----------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                | Attorney Docket Number | 70052.1418US01 |
|                                           |                                | Application Number     |                |
| Title of Invention                        | VEHICLE BASED RADAR UPSAMPLING |                        |                |

**Applicant Information:**

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                |                                                                        |       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|------------------------------------------------------------------------|-------|
| Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                |                                                                        |       |
| <b>Applicant 1</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                |                                                                        |       |
| If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section. |                                                                |                                                                        |       |
| <input type="button" value="Clear"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                |                                                                        |       |
| <input checked="" type="radio"/> Assignee                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <input type="radio"/> Legal Representative under 35 U.S.C. 117 | <input type="radio"/> Joint Inventor                                   |       |
| <input type="radio"/> Person to whom the inventor is obligated to assign.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                | <input type="radio"/> Person who shows sufficient proprietary interest |       |
| If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                |                                                                        |       |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                                                |                                                                        |       |
| Name of the Deceased or Legally Incapacitated Inventor: <input type="text"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                |                                                                        |       |
| If the Applicant is an Organization check here. <input checked="" type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                |                                                                        |       |
| Organization Name                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | FLIR Systems, Inc.                                             |                                                                        |       |
| <b>Mailing Address Information For Applicant:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                |                                                                        |       |
| Address 1                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | 27700 SW Parkway Avenue                                        |                                                                        |       |
| Address 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                                                |                                                                        |       |
| City                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Wilsonville                                                    | State/Province                                                         | OR    |
| Country                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | US                                                             | Postal Code                                                            | 97070 |
| Phone Number                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                | Fax Number                                                             |       |
| Email Address                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                |                                                                        |       |
| Additional Applicant Data may be generated within this form by selecting the Add button.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                |                                                                        |       |

**Assignee Information including Non-Applicant Assignee Information:**

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

|                                           |                                |                        |                |
|-------------------------------------------|--------------------------------|------------------------|----------------|
| <b>Application Data Sheet 37 CFR 1.76</b> |                                | Attorney Docket Number | 70052.1418US01 |
|                                           |                                | Application Number     |                |
| Title of Invention                        | VEHICLE BASED RADAR UPSAMPLING |                        |                |

|                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                |             |        |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|----------------|-------------|--------|
| <b>Assignee 1</b>                                                                                                                                                                                                                                                                                                                                                                                                                                      |            |                |             |        |
| Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication. |            |                |             |        |
| If the Assignee or Non-Applicant Assignee is an Organization check here. <input type="checkbox"/>                                                                                                                                                                                                                                                                                                                                                      |            |                |             |        |
| Prefix                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Given Name | Middle Name    | Family Name | Suffix |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                |             |        |
| <b>Mailing Address Information For Assignee including Non-Applicant Assignee:</b>                                                                                                                                                                                                                                                                                                                                                                      |            |                |             |        |
| Address 1                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                |             |        |
| Address 2                                                                                                                                                                                                                                                                                                                                                                                                                                              |            |                |             |        |
| City                                                                                                                                                                                                                                                                                                                                                                                                                                                   |            | State/Province |             |        |
| Country i                                                                                                                                                                                                                                                                                                                                                                                                                                              |            | Postal Code    |             |        |
| Phone Number                                                                                                                                                                                                                                                                                                                                                                                                                                           |            | Fax Number     |             |        |
| Email Address                                                                                                                                                                                                                                                                                                                                                                                                                                          |            |                |             |        |
| Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.                                                                                                                                                                                                                                                                                                                                      |            |                |             |        |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                        |            |                |             |        |

**Signature:**

**NOTE:** This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). However, if this Application Data Sheet is submitted with the **INITIAL** filing of the application and either box A or B is **not** checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

|                                                                                     |                                                                                     |           |                   |                     |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------|-------------------|---------------------|
| Signature                                                                           |  |           | Date (YYYY-MM-DD) | 2016-01-11          |
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| <b>Application Data Sheet 37 CFR 1.76</b> |                                | Attorney Docket Number | 70052.1418US01 |
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| Title of Invention                        | VEHICLE BASED RADAR UPSAMPLING |                        |                |

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## VEHICLE BASED RADAR UPSAMPLING

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Nicholas Högasten

## TECHNICAL FIELD

[0001] One or more embodiments of the invention relate generally to vehicle control devices and more particularly to, for example,  
10 vehicle object detection devices.

## BACKGROUND

[0002] The ability for a vehicle to quickly and accurately determine an environment around the vehicle or display a representation of the environment to an operator of the vehicle is  
15 desirable. Such an ability may be particularly desirable as autonomous vehicle technology becomes more common. Traditional systems for determining the environment around the vehicle may be expensive and inaccurate.

## SUMMARY

20 [0003] Systems and methods are disclosed herein for providing vehicle based radar upsampling. In certain embodiments, an apparatus may be provided. The apparatus may include an object detection device and a logic device. The object detection device may include a first distance sensor configured to detect objects  
25 within a first distance area and output first distance data and a first thermal sensor configured to detect thermal signatures within

a first thermal area and output first thermal data. The first distance area and the first thermal area may at least partially overlap. The logic device may be configured to receive the first distance data, receive the first thermal data, and generate, based, at least in part, on the first distance data and the first thermal data, a three-dimensional representation of a first overlapping area comprising the overlap of the first distance area and the first thermal area.

[0004] In an additional embodiment, a method may be provided.

The method may include receiving first distance data from a first distance sensor of an object detection device, where the first distance sensor is configured to detect objects within a first distance area, receiving first thermal data from a first thermal sensor of the object detection device, where the first thermal data is configured to detect thermal signatures within a first thermal area, and generating, based, at least in part, on the first distance data and the first thermal data, a three-dimensional representation of a first overlapping area comprising the overlap of the first distance area and the first thermal area.

[0005] The scope of the invention is defined by the claims, which are incorporated into this section by reference. A more complete understanding of embodiments of the invention will be afforded to those skilled in the art, as well as a realization of additional advantages thereof, by a consideration of the following detailed description of one or more embodiments. Reference will be made to the appended sheets of drawings that will first be described briefly.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Fig. 1 illustrates a block diagram of an object detection system in accordance with an embodiment of the disclosure.

[0007] Fig. 2 illustrates a vehicle equipped with an array of object detection devices in accordance with an embodiment of the disclosure.

[0008] Fig. 3 illustrates a flowchart of an object classification technique performed with an object detection system in accordance with an embodiment of the disclosure.

[0009] Fig. 4A illustrates an image with objects captured by an object detection device in accordance with an embodiment of the disclosure.

[0010] Fig. 4B illustrates an image with objects classified by an object detection device in accordance with an embodiment of the disclosure.

[0011] Embodiments of the invention and their advantages are best understood by referring to the detailed description that follows. It should be appreciated that like reference numerals are used to identify like elements illustrated in one or more of the figures.

#### DETAILED DESCRIPTION

[0012] Techniques and mechanisms are provided in accordance with one or more embodiments to image an environment around a vehicle, detect one or more objects around the vehicle, and/or identify and/or classify the objects around the vehicle. The vehicle may be any vehicle such as, for example, an aircraft, an automotive, a locomotive or train, a watercraft, a motorcycle, a hovercraft, a spacecraft, or another type of vehicle.

[0013] Certain embodiments may include one or more object detection devices. The object detection devices may include at least one distance sensor and at least one thermal sensor. The distance sensor and the thermal sensor of the object detection device may include overlapping fields of view. An area or volume may be imaged by the distance and thermal sensors. Data from the distance and/or thermal sensor may be used detect one or more objects within, at least, the field of view. The one or more objects detected may then be classified with data from the thermal sensor.

[0014] Fig. 1 illustrates a block diagram of an object detection system in accordance with an embodiment of the disclosure. Object detection system 100 in Fig. 1 may be used to capture and process data and images of an environment in accordance with various techniques described herein. Fig. 1 illustrates an object detection system 100 with an object detection device 102 communicatively connected to a control device 108. The object detection device 102 includes a distance sensor 106 and a thermal sensor 104. The distance sensor 106 and the thermal sensor 104 may be coupled by a mount 192. The mount 192 may couple the distance sensor 106 and the thermal sensor 104 in a fixed spatial relationship. The mount 192 may be a rigid structure and may be used to control the distance between the distance sensor 106 and the thermal sensor 104. The distance sensor 106 may be, for example, radar, lidar, a range finder, or another sensor that may provide spatial awareness (e.g., detect one or more objects located at a distance from the distance sensor 106 and/or determine the distance that the one or more objects are located at relative to the distance sensor 106). The thermal sensor 104 may be, for example, a thermal imaging camera such as a bolometer based camera or any other appropriate camera. Other embodiments of the object

detection device 102 may include other combinations of sensors, such as two or more distance sensors and/or two or more thermal sensors.

[0015] In certain embodiments, the distance sensor 106 and the thermal sensor 104 may be synchronized. That is, the distance sensor 106 and thermal sensor 104 may be calibrated to acquire images of and/or data associated with a scene 170. Accordingly, at least a portion of the scene 170 imaged by the distance sensor 106 may also be imaged by the thermal sensor 104. The thermal sensor 104 and the distance sensor 106 may acquire data (e.g., images, video, distance data, and/or other data) simultaneously or substantially simultaneously (e.g., during the same period). The data from the distance sensor 106 and the thermal sensor 104 may then be outputted to the control device 108 for processing via, for example, interfaces 116 and 114, respectively.

[0016] Object detection system 100 may include components distributed over multiple devices. In particular, the object detection device 102 may be in communication with the control device 108. Other embodiments may distribute the components to devices in other ways and may, in addition, distribute the components to three or more devices. Some such embodiments may distribute one, some, or all of the components of the object detection system 100 over the cloud. In the embodiment in Fig. 1, the interfaces 116 and 114 may communicatively connect the distance sensor 106 and the thermal sensor 104, respectively, to a communication component 152 of the control device 108. In various embodiments, the interfaces 116 and 114 may be a Bluetooth link, a WiFi link, a NFC link, a wired connection, or another type of link between the sensors 106 and 104 and the control device 108.

[0017] In certain embodiments, the control device 108 may include a processing component 110, a memory component 120, a display component 140, a second communication component 152, and a control component 150. The processing component 110 may include, for example, a microprocessor, a single-core processor, a multi-core processor, a microcontroller, a logic device (e.g., a programmable logic device configured to perform processing operations), a digital signal processing (DSP) device, one or more memories for storing executable instructions (e.g., software, firmware, or other instructions), and/or or any other appropriate combination of processing device and/or memory to execute instructions to perform any of the various operations described herein. The processing component 110 may be adapted to interface and communicate with components 120, 140, 150, and 152.

[0018] The processing component 110 (via the interfaces 116 and 114) may be adapted to data from the object detection device 102, process such data, store signals or data in the memory component 120, and/or retrieve stored signals or data from the memory component 120. Processing component 110 may be adapted to output data to the display component 140 for viewing by a user.

[0019] Display component 140 may include, in one embodiment, an image display device (e.g., a liquid crystal display (LCD)) or various other types of generally known video displays or monitors. Processing component 110 may be adapted to display data and information on display component 140.

[0020] In various aspects, display component 140 may be remotely positioned (e.g., housed in a separate housing) and processing component 110 may be adapted to remotely display data and information on display component 140 via wired or wireless communication with display component 140, as described herein.

[0021] Control component 150 includes, in one embodiment, a user input and/or interface device having one or more user actuated components, such as one or more push buttons, slide bars, rotatable knobs or a keyboard, that are adapted to generate one or more user actuated input control signals. Control component 150 may be adapted to be integrated as part of display component 140 to operate as both a user input device and a display device, such as, for example, a touch screen device adapted to receive input signals from a user touching different parts of the display screen.

Processing component 110 may be adapted to sense control input signals from control component 150 and respond to any sensed control input signals received therefrom.

[0022] Control component 150 may include, in one embodiment, a control panel unit (e.g., a wired or wireless handheld control unit) having one or more user-activated mechanisms (e.g., buttons, knobs, sliders, or others) adapted to interface with a user and receive user input control signals.

[0023] In another embodiment, control component 150 may include a graphical user interface (GUI), which may be integrated as part of display component 140 (e.g., a user actuated touch screen), having one or more images of the user-activated mechanisms (e.g., buttons, knobs, sliders, or others), which are adapted to interface with a user and receive user input control signals via the display component 140. As an example for one or more embodiments as discussed further herein, display component 140 and control component 150 may represent appropriate portions of an integrated display within a vehicle (such as a LED or LCD display), a multi-functional display, a smart phone, a tablet, a personal digital assistant (e.g., a wireless, mobile device), a laptop computer, a desktop computer, or other type of device.

[0024] In various embodiments, various components of the object detection system 100 may be combined and/or implemented or not, as desired or depending on application requirements. For example, processing component 110 may be combined with memory component 120, control component 150, display component 140, and/or communication component 152.

[0025] Fig. 2 illustrates a vehicle equipped with an array of object detection devices in accordance with an embodiment of the disclosure. Fig. 2 includes a vehicle 230 with a plurality of object detection devices 102-1-10 disposed at various positions of the vehicle 230. The vehicle 230 may be any vehicle such as, for example, an aircraft, an automotive, a locomotive or train, a watercraft, a motorcycle, a hovercraft, a spacecraft, or another type of vehicle.

[0026] The object detection devices 102-1-10 may be disposed on the outside of the vehicle 230, but other embodiments may dispose the object detection devices within the vehicle 230 or within certain housings on the vehicle 230. In certain embodiments where the object detection devices are mounted on an automobile, the object detection devices may, for example, be disposed of on the front, back, sides, roof, hood, trunk, windows, mirrors, and other portions of the vehicle 230. The object detection devices 102-1-10 may be arranged in a manner to allow for a full 360 degree coverage of the area around the vehicle. In certain other embodiments, the object detection devices may be arranged to cover areas of interest around the vehicle 230 (e.g., an area forward of the vehicle 230, an area backward of the vehicle 230, blindspots of the vehicle 230, and/or areas to the sides of the vehicle 230). As such, the object detection devices may detect the presence of objects around the vehicle 230 and classify such objects. The detection and

classification of objects may aid an operator or a navigational system (e.g., of an autonomous or partially autonomous control system of the vehicle 230 such as adaptive cruise control, autopilot, or full autonomous piloting) in the operation of the vehicle 230. The object detection devices 102-1-10 may output data to a control device 108 located within the vehicle 230, external to the vehicle 230, or distributed both internal and external to the vehicle 230.

[0027] Fig. 3 illustrates a flowchart of an object

classification technique performed with an object detection system in accordance with an embodiment of the disclosure. In block 302, one or more distance sensors may image or sense an area. In certain embodiments, such as embodiments where one or more distance sensors are radar sensors, the distance sensor data may be two-dimensional (2D) or three-dimensional (3D) radar data. In block 304, one or more thermal sensors may detect thermal signatures within the area. Data from the one or more distance sensors and the one or more thermal sensors may then be outputted to a control device.

[0028] In block 306, objects within the area may be detected.

The objects may be detected from, for example, the distance sensor data and/or the thermal sensor data. In certain embodiments, such as embodiments where one or more distance sensors may be radar sensors, the control device may, from data outputted by the one or more distance sensors, detect objects within the area (e.g., may detect objects through the reflection of radar signals from the radar sensor). Additionally, the control device may also determine that the objects are at a certain distance and/or within a certain plane located at a certain distance. In certain such embodiments,

the control device may compensate for the Doppler effect when distances are determined while the vehicle is moving.

[0029] In certain other embodiments, the control device may detect objects with data from, at least, the one or more thermal sensors by, for example, detecting objects via thermal signature. For example, certain objects, such as humans, animals, or vehicles, may be significantly warmer than the surrounding environment and thus may emit a thermal signature that is significantly warmer than the environment. The control device may detect such thermal signatures and determine the presence of objects from the signatures.

[0030] After the object has been detected, it may be classified in block 308. Classification may be performed using, for example, the distance sensor data and/or the thermal sensor data. Distance sensor data may be used to, for example, determine a shape of the object and classify the object, at least partially, due to the size and/or shape of the object. Additionally or alternatively, thermal sensor data may be used to, for example, determine a temperature of the object and classify the object, at least partially, due to the temperature of the object. For example, a certain animal may be known to have a body temperature of X while another animal may be known to have a body temperature of Y. Thus, if a detected object about the size of both animals has a body temperature of Y, it may be classified to be animal Y. The techniques may additionally be combined, such that if an object is a certain size, only known temperatures for objects of such sizes may be referred to for determining the classification of the object.

[0031] In block 310, a representation of the environment, that may include the objects detected, may be generated. The representation may, in certain embodiments, be used by the vehicle

for piloting (e.g., autopilot, adaptive cruise control, and/or autonomous piloting) purposes. Other embodiments, may output the representation onto, for example, a display component for communication to an operator of the vehicle.

5    **[0032]**     The representation may be generated from data from the one or more distance sensors and/or data from the one or more thermal sensors. In certain embodiments, objects detected and classified in blocks 306 and 308 may be displayed and/or highlighted within the representation. Additionally, in certain  
10   embodiments, data from the one or more distance sensors and/or the one or more thermal sensors may be used as part of an interpolation, warping, and/or upsampling process. Such processes may be performed to, for example, sharpen terrain, objects, and other features within the representation. A function may be  
15   utilized for such processes in order to interpolate, warp, and/or upsample data from the distance sensor, the thermal sensor, or from another sensor such as a visual sensor. Such functions may, in certain embodiments, be determined, at least in part, responsive to data from the one or more distance sensors or data from the one or  
20   more thermal sensors. In such embodiments, the higher resolution signal of the distance sensor or the thermal sensor may be used to improve resampling and/or upsampling of the lower resolution signal of the distance sensor or the thermal sensor for any two-dimensional or three-dimensional representations.

25   **[0033]**     For example, in such embodiments, the distance sensor data may be lower resolution than the thermal sensor data (or vice versa). The data with the lower resolution (e.g., the distance sensor data in the above example) may be resampled (e.g., upsampled) to match the resolution of the data with the higher  
30   resolution. In such embodiments, the higher resolution data may be

used to guide the resampling of the lower resolution data to more accurately depict terrain, objects, and/or other features in the representation. As such, the higher resolution data may guide the determination of the function for such resampling. Such

5 interpolation, warping, upsampling, and/or resampling may be performed by, for example, systems and techniques described in U.S. Provisional Application No. 62/276,800, entitled "Systems and Methods for Image Resolution Enhancement" which is herein incorporated by reference in its entirety.

10 [0034] In certain embodiments, the technique illustrated in Fig. 3 may be performed in different orders. Additionally, the technique may be performed with few or additional steps. For example, certain embodiments may omit blocks 306 and 308, or block 310 may be performed before blocks 306 and 308.

15 [0035] Fig. 4A illustrates an image with objects captured by an object detection device in accordance with an embodiment of the disclosure. Fig. 4A illustrates a thermal representation 400A of an area captured by a thermal sensor and sparse planes 400B of a distance sensor. The distance sensor may be, for example, a radar  
20 sensor and the sparse planes may represent, for example, various planes of detection of the distance sensor.

[0036] The thermal representation 400A may be a representation of the area by a single planar view (e.g., a two-dimensional representation). The thermal representation 400A may include  
25 representations (e.g., thermal readings or images) of persons 482 and 484 and vehicle 486.

[0037] Sparse planes 400B may be representations of the area detected by the distance sensor. The distance sensor may detect objects located at different distances and may also determine the

distances that the objects are located at. As such, the distance sensor may generate a three-dimensional (and in some cases, "four-dimensional" due to compensation for any Doppler effect) representation of the area via, for example, the sparse planes 400B. The distance sensor may, in certain embodiments such as embodiments where the distance sensor is a radar sensor, image, scan, and/or emit signals directed towards a line or plane within the area. For example, in 3D radar embodiments, the distance sensor may image, scan, and/or emit signals directed towards one or more sparse planes and may cycle through imaging, scanning, and/or emitting signals directed towards a plurality of sparse planes where the sparse planes are located at different distances from the distance sensor. Accordingly, the sparse planes 400B may represent the plurality of different sparse planes imaged, scanned, and/or detected via emitted signals by the distance sensor. One or some of the spare planes 400B may include data detecting the persons 482 and/or 484 and/or the vehicle 486 within the sparse planes 400B.

[0038] Fig. 4B illustrates an image with objects classified by an object detection device in accordance with an embodiment of the disclosure. In Fig. 4B, the sparse planes 400B may include a first sparse plane 490A, a second sparse plane 490B, a third sparse plane 490C, a fourth sparse plane 490D, and other sparse planes. A control device of the vehicle may classify the objects within the thermal representation 400A based, at least in part, on data from the distance sensor. For example, the control device may determine that the distance sensor has detected a first object within the first sparse plane 490A, a second object within the third sparse plane 490C, and a third object within the fourth sparse plane 490D. The control device may then determine that the person 482 may be detected within the fourth sparse plane 490D, the person 484 may be detected within the third sparse plane 490C, and the vehicle 486

may be detected within the first sparse plane 490A. Accordingly, the control device may then determine the distances that the persons 482 and 484 and the vehicle 486 are located at relative to the object detection device and/or the vehicle that the object  
5 detection device is coupled to.

[0039] The control device may determine which of the sparse planes the objects (e.g., person 482 and/or 484 and/or the vehicle 486) are located within by, for example, matching a size of the thermal reading and/or image with the size of an object detected  
10 within a sparse plane and/or matching a position of the object within the two-dimensional thermal representation 400A with the position of an object within a sparse plane. As such, in certain embodiments, an enhanced thermal representation with distance data and/or a three dimensional thermal representation may be generated.

15 [0040] In certain embodiments, the classification and/or matching of the objects may be performed according to an order. For example, in one embodiment, the closest and/or nearest object detected by the distance sensor may be matched to a thermal reading or thermal image detected by the thermal sensor in the same cone  
20 angle as that of the object detected within sparse plane (e.g., if a straight line is drawn from the object detection device to the object, the angle of the straight line would be the same or substantially similar within the distance sensor and the thermal sensor). The second closest and/or nearest object detected may  
25 then be matched to a second thermal reading or thermal image in the corresponding same cone angle as the second object. Such a process may be repeated for each object detected until all objects have been matched.

[0041] In various embodiments, a network may be implemented as a  
30 single network or a combination of multiple networks. For example,

in various embodiments, the network may include the Internet and/or one or more intranets, landline networks, wireless networks, and/or other appropriate types of communication networks. In another example, the network may include a wireless telecommunications network (e.g., cellular phone network) adapted to communicate with other communication networks, such as the Internet. As such, in various embodiments, the imaging system 100A may be associated with a particular network link such as for example a URL (Uniform Resource Locator), an IP (Internet Protocol) address, and/or a mobile phone number.

[0042] Where applicable, various embodiments provided by the present disclosure can be implemented using hardware, software, or combinations of hardware and software. Also where applicable, the various hardware components and/or software components set forth herein can be combined into composite components comprising software, hardware, and/or both without departing from the spirit of the present disclosure. Where applicable, the various hardware components and/or software components set forth herein can be separated into sub-components comprising software, hardware, or both without departing from the spirit of the present disclosure. In addition, where applicable, it is contemplated that software components can be implemented as hardware components, and vice-versa.

[0043] Software in accordance with the present disclosure, such as non-transitory instructions, program code, and/or data, can be stored on one or more non-transitory machine readable mediums. It is also contemplated that software identified herein can be implemented using one or more general purpose or specific purpose computers and/or computer systems, networked and/or otherwise. Where applicable, the ordering of various steps described herein

can be changed, combined into composite steps, and/or separated into sub-steps to provide features described herein.

[0044] Embodiments described above illustrate but do not limit the invention. It should also be understood that numerous  
5 modifications and variations are possible in accordance with the principles of the invention. Accordingly, the scope of the invention is defined only by the following claims.

## CLAIMS

What is claimed is:

1. An apparatus comprising:

an object detection device comprising:

5 a first distance sensor configured to detect objects within a first distance area and output first distance data, and

a first thermal sensor configured to detect thermal signatures within a first thermal area and output first thermal data, wherein the first distance area and the first thermal area at least partially overlap; and

a logic device configured to:

receive the first distance data,

receive the first thermal data, and

15 generate, based, at least in part, on the first distance data and the first thermal data, a three-dimensional representation of a first overlapping area comprising the overlap of the first distance area and the first thermal area by, at least, interpolating, warping, and/or upsampling, with  
20 a function, one of the first distance data or the first thermal data, wherein the function is determined, at least in part, with the other of the first distance data or the first thermal data.

2. An apparatus comprising:

an object detection device comprising:

a first distance sensor configured to detect objects within a first distance area and output first distance data,  
5 and

a first thermal sensor configured to detect thermal signatures within a first thermal area and output first thermal data, wherein the first distance area and the first thermal area at least partially overlap; and

10 a logic device configured to:

receive the first distance data,

receive the first thermal data, and

generate, based, at least in part, on the first distance data and the first thermal data, a three-dimensional  
15 representation of a first overlapping area comprising the overlap of the first distance area and the first thermal area.

3. The apparatus of claim 2, wherein the logic device is further configured to:

20 determine, with the first distance data, a first object within the first overlapping area with the first distance data; and  
classify, with the first thermal data, the first object.

4. The apparatus of claim 3, wherein the logic device is further configured to determine, with the first distance data, a first object distance.

5 5. The apparatus of claim 3, wherein:

the object detection device further comprises a second thermal sensor configured to detect thermal signatures within a second thermal area and output second thermal data, wherein the first distance area, the first thermal area, and the second thermal  
10 area at least partially overlap; and

the logic device is further configured to:

receive the second thermal data, and

determine, based on the first thermal data and the second thermal data, a first object distance.

15

6. The apparatus of claim 3, wherein the logic device is further configured to:

determine, with the first distance data, a second object within the first overlapping area; and

20 classify, with the first thermal data, the second object within the first overlapping area.

7. The apparatus of claim 6, wherein the first object is located at a first distance from the object detection device, the

second object is located at a second distance from the object detection device, and the logic device is further configured to:

determine, with the first distance data, a first object distance associated with the first distance; and

5           determine, with the first distance data, a second object distance associated with the second distance.

8.   The apparatus of claim 2, wherein the object detection device is a first object detection device and further comprising:

10           a second objection detection array comprising:

          a second distance sensor configured to detect objects within a second distance area and output second distance data, and

          a second thermal sensor configured to detect thermal  
15       signatures within a second thermal area and output second thermal data, wherein the second distance area and the second thermal area at least partially overlap and the logic device is further configured to:

          receive the second distance data;

20           receive the second thermal data, wherein the three-dimensional representation is generated based, additionally, on the second distance data and the second thermal data, wherein the three-dimensional representation further comprises a representation of a

second overlapping area comprising the overlap of the second distance area and the second thermal area.

9. The apparatus of claim 2, wherein the first distance  
5 sensor is a radar based sensor and/or a lidar based sensor.

10. The apparatus of claim 2, where the logic device is further configured to output the three-dimensional representation to a user interface.

10

11. The apparatus of claim 2, further comprising a mobile structure, wherein the object detection device is coupled to the mobile structure.

15 12. The apparatus of claim 11, wherein the mobile structure comprises a plurality of object detection devices such that each object detection device comprises a distance sensor and a thermal sensor.

20 13. The apparatus of claim 12, wherein the plurality of object detection devices are coupled to the mobile structure such that the overlapping areas of the distance sensors and thermal sensors of the object detection devices form a 360 degree coverage of an area around the mobile structure and the three-dimensional

representation generated by the logic device comprises at least a representation of the 360 degree coverage of the area.

14. A method comprising:

5 receiving first distance data from a first distance sensor of an object detection device, wherein the first distance sensor is configured to detect objects within a first distance area;

receiving first thermal data from a first thermal sensor  
10 of the object detection device, wherein the first thermal data is configured to detect thermal signatures within a first thermal area; and

generating, based, at least in part, on the first distance data and the first thermal data, a three-dimensional  
15 representation of a first overlapping area comprising the overlap of the first distance area and the first thermal area.

15. The method of claim 14, further comprising:

determining, with the first distance data, a first object  
20 within the first overlapping area with the first distance data; and  
classifying, with the first thermal data, the first object.

16. The method of claim 15, further comprising determining, with the first distance data, a first object distance.

17. The method of claim 15, further comprising:

5 receiving second thermal data from a second thermal sensor of the object detection device, wherein the second thermal data is configured to detect thermal signatures within a second thermal area, wherein the first distance area, the first thermal area, and the second thermal area at least partially overlap; and  
10 determining, based on the first thermal data and the second thermal data, a first object distance.

18. The method of claim 15, further comprising:

determining, with the first distance data, a second  
15 object within the first overlapping area; and  
classifying, with the first thermal data, the second object within the first overlapping area.

19. The method of claim 18, wherein the first object is  
20 located at a first distance from the object detection device, the second object is located at a second distance from the object detection device, and the logic device is further configured to:  
determine, with the first distance data, a first object distance associated with the first distance; and

determine, with the first distance data, a second object distance associated with the second distance.

20. The method of claim 14, further comprising:

5           receiving second distance data from a second distance sensor, wherein the second distance sensor is configured to detect objects within a second distance area; and

          receiving second thermal data from a second thermal sensor, wherein the second thermal data is configured to detect  
10 thermal signatures within a second thermal area, wherein the three-dimensional representation is generated based, additionally, on the second distance data and the second thermal data, and wherein the three-dimensional representation further comprises a representation  
15 of a second overlapping area comprising the overlap of the second distance area and the second thermal area.

21. The method of claim 14, further comprising outputting the three-dimensional representation to a user interface.

## ABSTRACT

Various embodiments of the present disclosure may include one or more object detection devices. The object detection devices may include at least one distance sensor such as a radar, lidar, or  
5 other distance sensor and at least one thermal sensor such as a thermal imaging device. One or more object detection devices may be mounted to vehicles to provide enhanced representations of an area around the vehicles.

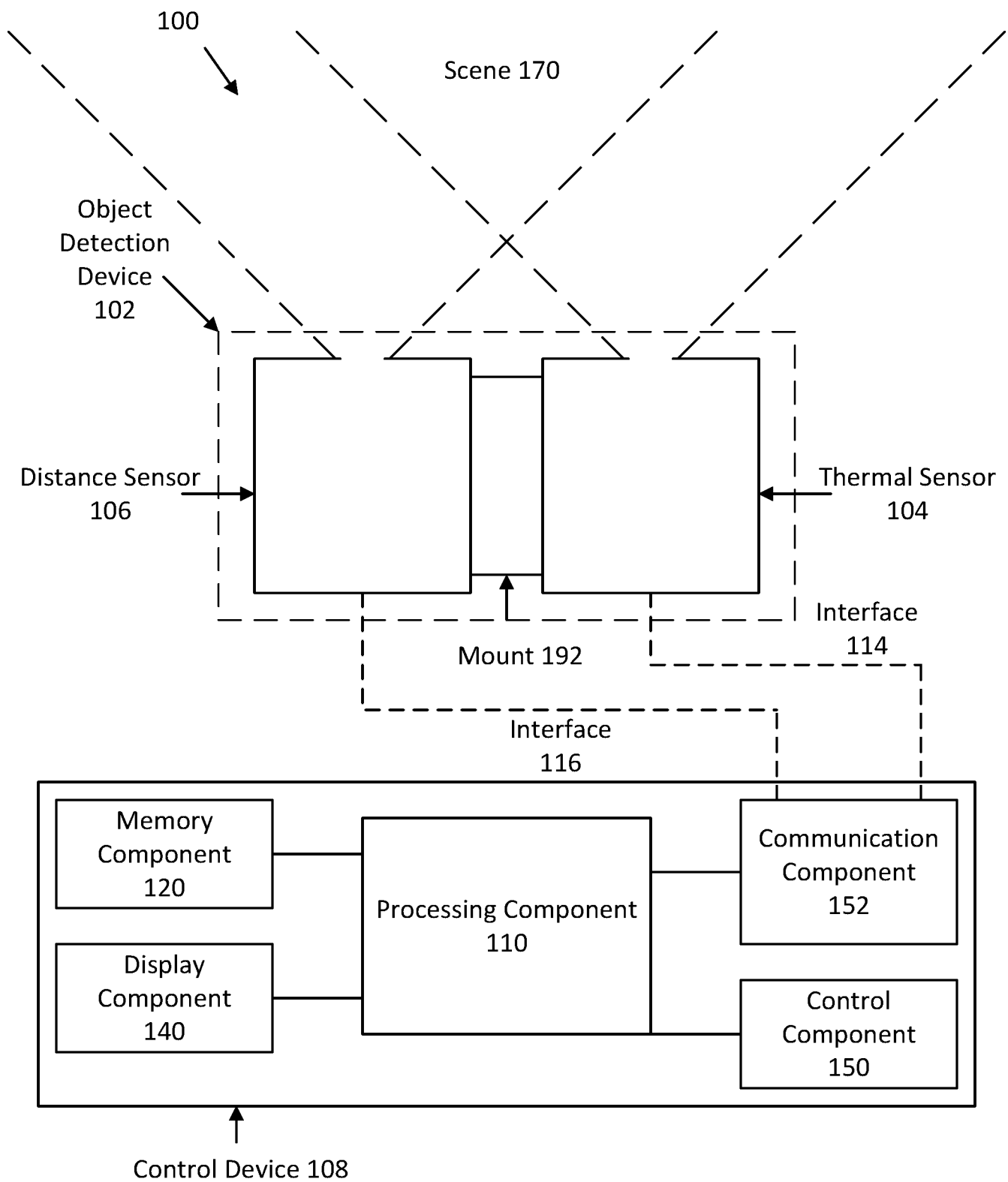


**FIG. 1**

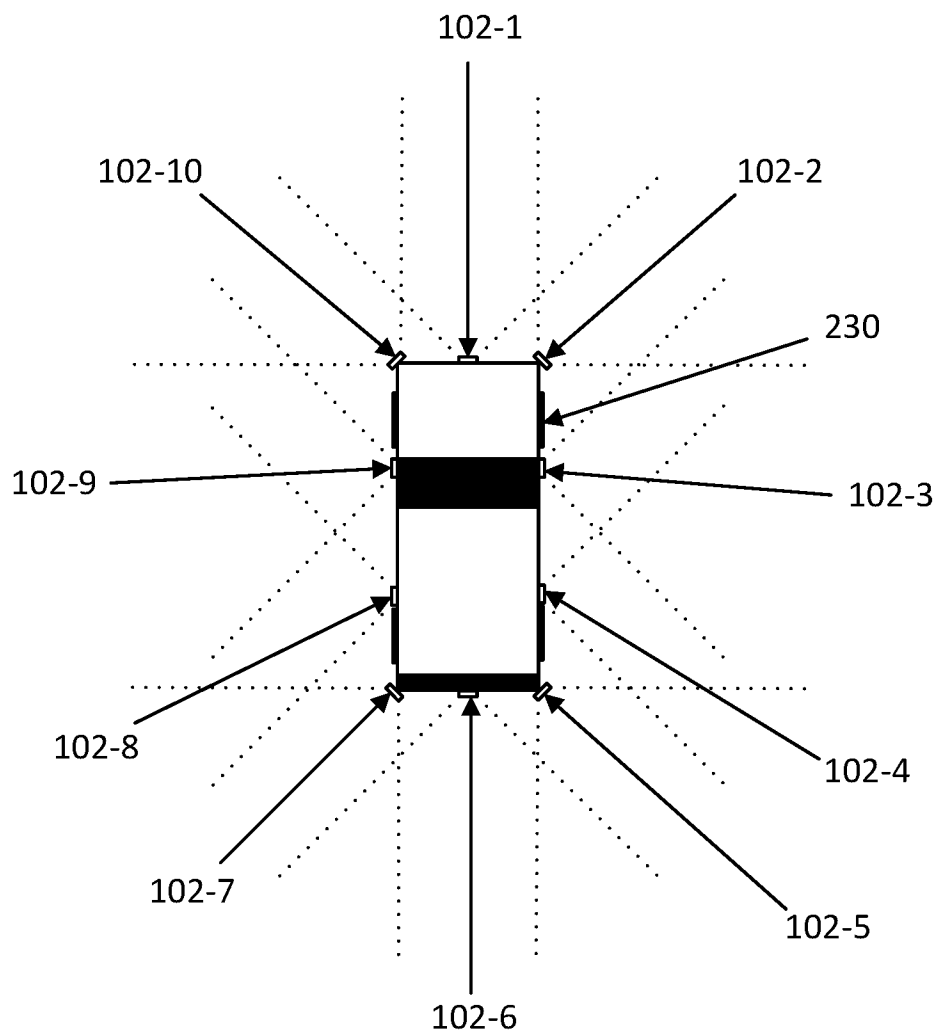


**FIG. 2**

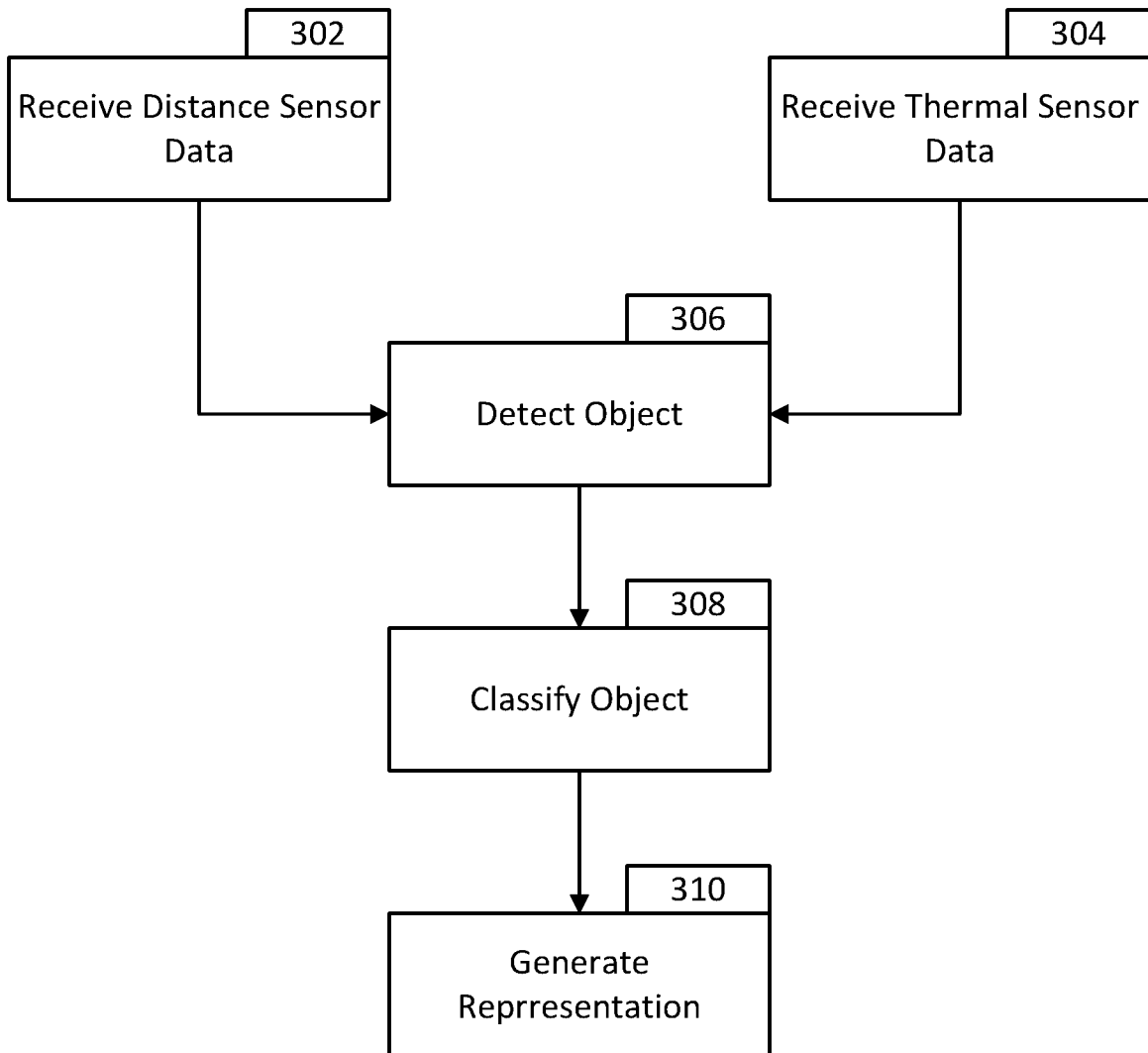


**FIG. 3**

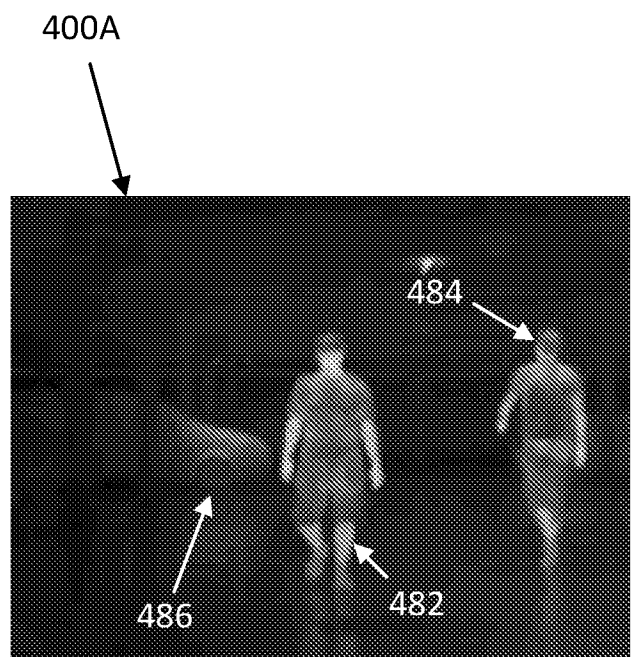
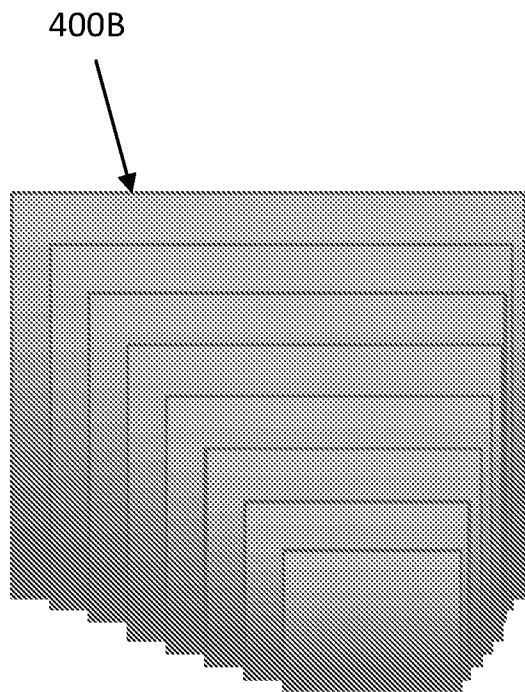


**FIG. 4A**

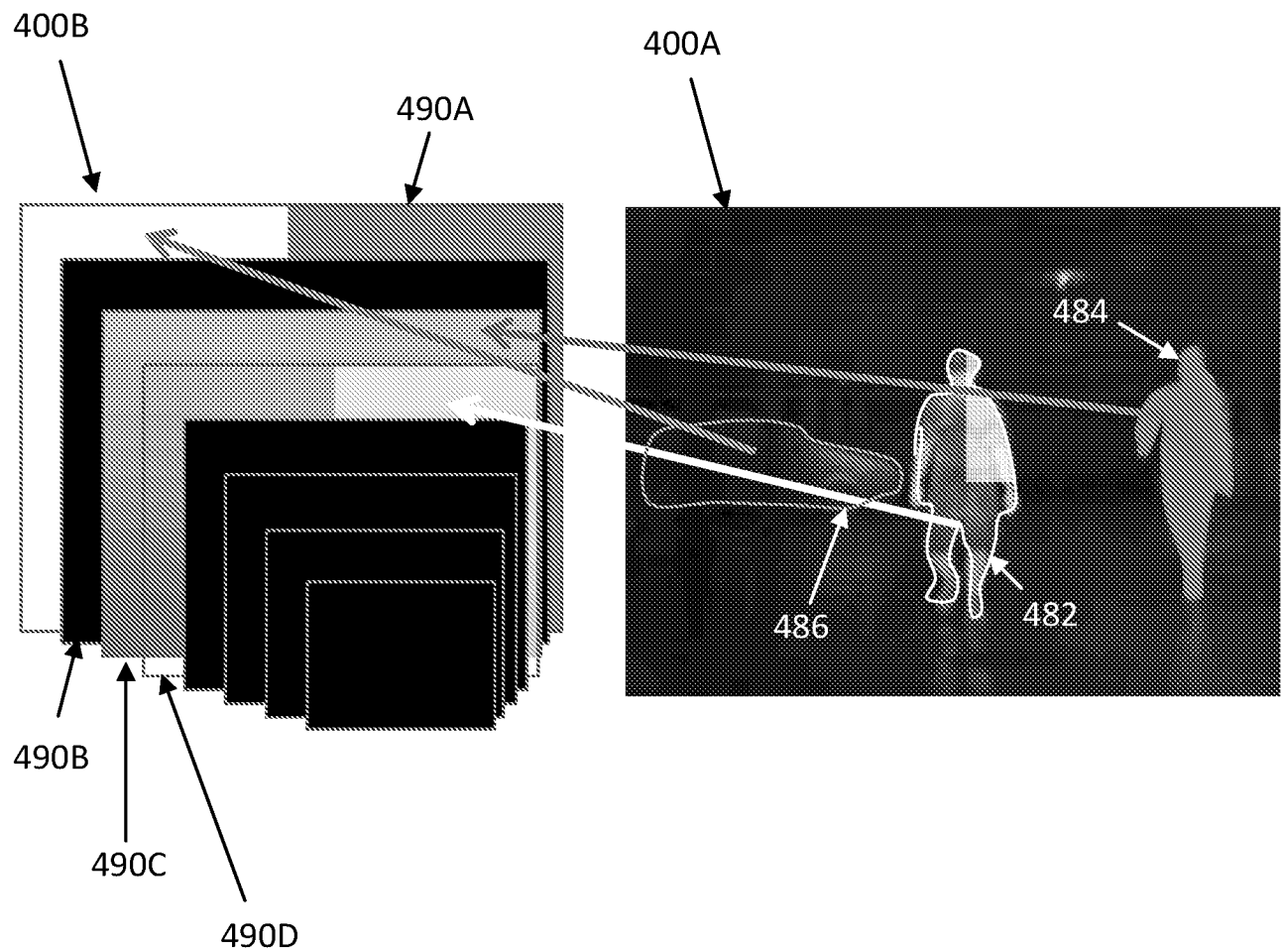


**FIG. 4B**

## Electronic Patent Application Fee Transmittal

|                                             |                                     |                 |               |                             |
|---------------------------------------------|-------------------------------------|-----------------|---------------|-----------------------------|
| <b>Application Number:</b>                  |                                     |                 |               |                             |
| <b>Filing Date:</b>                         |                                     |                 |               |                             |
| <b>Title of Invention:</b>                  | VEHICLE BASED RADAR UPSAMPLING      |                 |               |                             |
| <b>First Named Inventor/Applicant Name:</b> | Nicholas Hogasten                   |                 |               |                             |
| <b>Filer:</b>                               | Gregory J. Michelson/Tina Kavanaugh |                 |               |                             |
| <b>Attorney Docket Number:</b>              | 70052.1418US01                      |                 |               |                             |
| Filed as Large Entity                       |                                     |                 |               |                             |
| <b>Filing Fees for Provisional</b>          |                                     |                 |               |                             |
| <b>Description</b>                          | <b>Fee Code</b>                     | <b>Quantity</b> | <b>Amount</b> | <b>Sub-Total in USD(\$)</b> |
| <b>Basic Filing:</b>                        |                                     |                 |               |                             |
| Provisional Application Filing              | 1005                                | 1               | 260           | 260                         |
| <b>Pages:</b>                               |                                     |                 |               |                             |
| <b>Claims:</b>                              |                                     |                 |               |                             |
| <b>Miscellaneous-Filing:</b>                |                                     |                 |               |                             |
| <b>Petition:</b>                            |                                     |                 |               |                             |
| <b>Patent-Appeals-and-Interference:</b>     |                                     |                 |               |                             |
| <b>Post-Allowance-and-Post-Issuance:</b>    |                                     |                 |               |                             |

| Description        | Fee Code | Quantity | Amount | Sub-Total in USD(\$) |
|--------------------|----------|----------|--------|----------------------|
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| Miscellaneous:     |          |          |        |                      |
| Total in USD (\$)  |          |          |        | 260                  |

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| <b>EFS ID:</b>                              | 24587339                            |
| <b>Application Number:</b>                  | 62277186                            |
| <b>International Application Number:</b>    |                                     |
| <b>Confirmation Number:</b>                 | 2583                                |
| <b>Title of Invention:</b>                  | VEHICLE BASED RADAR UPSAMPLING      |
| <b>First Named Inventor/Applicant Name:</b> | Nicholas Hogasten                   |
| <b>Customer Number:</b>                     | 85112                               |
| <b>Filer:</b>                               | Gregory J. Michelson/Tina Kavanaugh |
| <b>Filer Authorized By:</b>                 | Gregory J. Michelson                |
| <b>Attorney Docket Number:</b>              | 70052.1418US01                      |
| <b>Receipt Date:</b>                        | 11-JAN-2016                         |
| <b>Filing Date:</b>                         |                                     |
| <b>Time Stamp:</b>                          | 15:51:55                            |
| <b>Application Type:</b>                    | Provisional                         |

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| Authorized User                          | MICHELSON, GREGORY J. |

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|-----------------|--------------------------------|-------------------------------|---------------------------------------------------|------------------|------------------|
| 1               | Provisional Cover Sheet (SB16) | 1418ProvisionalCoverSheet.pdf | 575337<br>9ddee611c5a2df2258008bcb1e0b9ba24f1d00c | no               | 3                |

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|   |                        |             |                                                     |    |   |
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| 2 | Application Data Sheet | 1418ADS.pdf | 1491322<br>05a00f249e1a26cede2e61909837f1565538dae3 | no | 8 |
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| 3 |  | 1418Application.pdf | 3443071<br>223a0f559d49fa8ef1c9550a9ae3e4ce42dd6853 | yes | 25 |
|---|--|---------------------|-----------------------------------------------------|-----|----|

### Multipart Description/PDF files in .zip description

| Document Description | Start | End |
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| Specification        | 1     | 16  |
| Claims               | 17    | 24  |
| Abstract             | 25    | 25  |

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|---|---------------------------------------------------|----------------------|----------------------------------------------------|----|---|
| 4 | Drawings-other than black and white line drawings | 1418US01Drawings.PDF | 117566<br>ebd806e4151a32623da14295a51f41aa58550b26 | no | 5 |
|---|---------------------------------------------------|----------------------|----------------------------------------------------|----|---|

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|---|----------------------|--------------|---------------------------------------------------|----|---|
| 5 | Fee Worksheet (SB06) | fee-info.pdf | 29943<br>09e7407ea0f2f9c113eb9ccc3c30f58f3bb6fbd7 | no | 2 |
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