# List of materials (Note that all the listed artefacts should be uploaded to the correct SharePoint Prototype Folder)

## Front End: (Ethan double check)

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| --- | --- |
| Device | Components coding files... |
| Follower sheep F1001 | Arduino: Upload the Follower\_to\_leader sketch file to board  Blue Fruit: Connect to Arduino  9V battery: To power the Arduino |
| Follower sheep F1002 | Arduino: Upload the Follower\_to\_leader sketch file to board  Blue Fruit: Connect to Arduino  9V battery: To power the Arduino |
| Leader sheep L1000 | Download the BlueConnect App |

## Backend (Emre double check)

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| Device? | Files for submission |
| UI |  |
| Database |  |
| Frontend Receiver | Arduino + BlueFruit: sheepid sketch folder to update the sheep ids  Arduino + BlueFruit: GPS sketch folder to update the locations |

## Physical Collar (Yiqun could you finish this part?)

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| Cover | Maintain the waterproof to the system |
| Middle layer | Contain the Bluefruit and battery |
| Base | Contain the Arduino |
| Buckle | Connect the case to sheep |

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| Verification |  |
| Buckle | Is that easy to use the buckle  Is the stable when they are linked |
| Case | Waterproof test  Is the case possible to protect the components |

# Basic functionality tests verification (Does it work technically? No bugs?)

## Frontend (Ethan could you double check this)

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|  | Testing | Expected Outcome | Important tasks |
| RSSI clustering | When connecting:  1.Set the RSSI value to be 75 dBm.  2.Put F1001 close (within 5 meters) and F1002 far (around 10 meters). | F1001 should be found, F1002 should not be found.  F1001 is found, F1002 is not found | Build a calibration curve of RSSI versus distance to find the optimum RSSI threshold value.  Record the farthest detecting range of the Bluetooth RSSI, use this to calculate the minimum needed leader sheep percentage for 150 sheep assuming each sheep has a activity range of 2 meters and leader sheep are distributed evenly. (this is used for the validation) |
|  | When connected in multiple UART mode:  1.Move F1002 out of the RSSI range.  2.Then move F1002 back into the RSSI range. | F1002 should be disconnected/disappears then F1002 re-appears.  Testing output:  The peripherals cannot disconnect according to a set threshold, only if when we move out of the range of –100dBm.  Once it disconnects, we must reconnect manually. Filtering according to RSSI can be done when connecting. |  |
| Leader to Follower Broadcast and Follower to Leader respond | 1.Send “L1000” from the Bluefruit Connet app UART to F1001 and F1002.  2.Check the responses on the app UART. | Both sheep immediately respond “F1001” and “F1002” to the UART on the phone. | Should broadcast to the follower sheep every 10 minutes. Calculate the GSM transmission speed. |
| Leader to Backend GPS | 1.Run the GPS sketch file, the locations will be sent automatically. | Successfully sent |  |
| Leader to Frontend sheepids | 2.Run the sheepid file, then type the received sheep ids into the UART in the form of “L1000” plus the response from the follower sheep. | Successfully sent |  |

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| -45 dBm | -55dBm | -65dBm | -75dBm | -80 dBm | -90 dBm |
| 0m | 0.5m | 1m | 5m | 12m | 30m |

Backend Emre could you make a table that is similar to the above two tables for the backend?

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|  | Testing | Expected Output | Important tasks |
| UI | Run the Arduino and send the messages | Should be able to load the data real-time when click on the load button | Translate into two languages |
| Serial Monitor Listener | Send “UPDATE\_LATITUDE = 12.12345, LONGITUDE = 10.12345\_L1000F1001F1002” | Should be able to record this in the SHEEP db |  |
| Backend SHEEPS.db | Use the db browser to see | A table should be seen |  |
| Missing sheep detecting, Backend MISSING.db | See table below | All results should match the provided results, and the missed sheep should show on the UI when load button is clicked. |  |
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| Update 1  (Initialization at 9am) | Leader sheep id (1000) | Leader sheep location (“17.911847, 36.436322”) | Cluster sheep  (1001, 1002, 1003, 1004, 1005) | Send  “UPDATE\_LATITUDE = 17.911847, LONGITUDE = 36.436322\_L1000F1001F1002F1003F1004F1005”  “UPDATE\_LATITUDE = 10.015827, LONGITUDE = 10.386621\_L2000F2001F2002F2003F2004F2005”  “UPDATE\_LATITUDE22.063343, LONGITUDE = 38.435378\_L3000F3001F3002”  Result is no missing |
| Leader sheep id (2000) | Leader sheep location (“10.015827, 10.386621”) | Cluster sheep  (2001, 2002, 2003, 2004, 2005) |
| Leader sheep id (3000) | Leader sheep location (“22.063343, 38.435378”) | Cluster sheep  (3001, 3002) |
| Update 2  (9:10 am)  (case 1, no missing sheep, just sheep walking to other clusters) | Leader sheep id (1000) | Leader sheep location (“17.800000, 36.300000”) | Cluster sheep  (1001, 2001, 1002, 1003, 1005) | “UPDATE\_LATITUDE = 17.800000, LONGITUDE = 36.300000\_L1000F1001F2001F1002F1003F1005”  No missing |
| Leader sheep id (2000) | Leader sheep location (“10.100000, 10.300003”) | Cluster sheep  (2002, 2003, 2004, 2005) | “UPDATE\_LATITUDE = 10.100000, LONGITUDE = 10.300003\_L2000F2002F2003F2004F2005”  no missing |
| Leader sheep id (3000) | Leader sheep location (“22.060000, 38.400000”) | Cluster sheep  (3001, 3002, 1004) | “UPDATE\_LATITUDE = 22.060000, LONGITUDE = 38.400000\_L3000F3001F3002F1004”  no missing |
| Update 3  (9:20 am)  (case 2, missing follower sheep) | Leader sheep id (1000) | Leader sheep location (“17.800005, 36.300005”) | Cluster sheep  (1001, 2001, 1002, 1003, 1005) | “UPDATE\_LATITUDE = 17.800005, LONGITUDE = 36.300005\_L1000F1001F2001F1002F1003F1005”  No missing |
| Leader sheep id (2000) | Leader sheep location (“10.100005, 10.300005”) | Cluster sheep  (2001, 2002, 2003, 2004, 2005) | “UPDATE\_LATITUDE = 10.100005, LONGITUDE = 10.300005\_L2000F2001F2002F2003F2004F2005”  no missing (duplicate case: we found 2001 twice but this should not cause any errors) |
| Leader sheep id (3000) | Leader sheep location (“22.060005, 38.400005”) | Cluster sheep  (3001, 3002) | “UPDATE\_LATITUDE = 22.060005, LONGITUDE = 38.400005\_L3000F3001F3002”  **REPORT MISSING id 1004, location, (“22.060005, 38.400005”)** |
| Update 4  (9:30 am)  (case 3, a missing leader sheep | Leader sheep id (1000) | Leader sheep location (“17.800005, 36.300002”) | Cluster sheep  (1001, 2001, 1002, 1003, 1005) | “UPDATE\_LATITUDE = 17.800005, LONGITUDE = 36.300002\_L1000F1001F2001F1002F1003F1005”  No missing |
| Leader sheep id (2000) | Leader sheep location (“10.100003, 10.300005”) | Cluster sheep  (2001, 2002, 2003, 2004, 2005, 3001, 3002) | “UPDATE\_LATITUDE = 10.100003, LONGITUDE = 10.300005\_L2000F2001F2002F2003F2004F2005F3001F3002”  No missing |
| Leader sheep id (3000) | Leader sheep location (“22.060008, 38.400005”) | Cluster sheep | “UPDATE\_LATITUDE = 22.060008, LONGITUDE = 38.400005\_L3000”  **REPORT MISSING id 3000, location, (“22.060008, 38.400005”)** |
| ~~Update 4~~  ~~(9:40 am)~~  ~~(case 4, missing a whole cluster of sheep~~  ~~I guess we are not going to do this~~ | ~~Leader sheep id (10000)~~ | ~~Leader sheep location (“17.800025, 36.300003”)~~ | ~~Cluster sheep~~  ~~(10001, 20001, 10005, 10004)~~ | ~~Repeat the same, no missing~~ |
| ~~Leader sheep id (20000)~~ | ~~Leader sheep location (“10.100003, 10.300015”)~~ | ~~Cluster sheep~~  ~~(20001, 20002, 20004, 20005, 30001, 30002)~~ | ~~Repeat the same, no missing~~ |
| ~~Leader sheep id (30000)~~ | ~~Leader sheep location (“22.160008, 38.300003”) (this location is exaggerated, may need to test)~~ | ~~Cluster sheep~~  ~~(20003, 10002, 10003)~~ | ~~if the gps location is farther than the range.~~  **~~REPORT MISSING id 30000, 20003, 10002, 10003, location, (“22.160008, 38.300003”)~~** |

Physical Collar Yiqun could you make a table that is similar to the above two tables for the physical collar?

# Product validation test (When scaling it up for real product, will the customer be satisfied?)

1. Cost Efficiency

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| Requirement | Cost Efficiency, Affordability |
| Metric | South African Rand (R1 ≈ 0.084 CAD) |
| Criteria | Lower price is preferred |
| Constraint | Must not exceed R57000/yr or R380/sheep/yr  or  Should not exceed R9000/yr or R60/sheep/yr  $12 $30 for 150 sheep |
| Testing | Sum up all costs of components for a single product \* how much is needed / how many years it can be used for |

1. Functionality – Frontend + Backend

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| Requirement | Identify when sheep are lost (notification system) [1]  Backend missing sheep detecting program + Frontend when it disappears |
| Requirement 1 | Synchronization of notification creation |
| Metric | Time used (mins) for data entry/extraction |
| Criteria | Shorter time is preferred |
| Constraint | Must be less than 10 mins [2]  Should be below 7 mins, according to US EMS notification time in rural area |
| Testing | Use a timer to time when sheep1 disappears from the Bluetooth monitor when it goes out of the range.  Backend: just run the program |
| Note/Results | Frontend notification: simultaneous (Test needed)  Backend detection: ^ time |
| Requirement 2 | Reliability of the notification communication |
| Metric | Percentage error of false alert (%) |
| Criteria | Lower error is preferred |
| Constraints | Be able to create and send notifications in various environments (land, ditches, homesteads, water, bushes, forests) |
| Must work with lands, ditches, homesteads. |
| Be able to identify: 1. when sheep wander off by themselves 2. when groups of sheep meet 3. when sheep follow other groups |
| Must identify 1 and 3 as sheep lost alert.  Should identify 2 as high sheep lost risk alert. [11] |
| Should allow notification documentation, record all the history notifications [11] |
| Testing | 70 test trials:  % error = (# of failed trials based on constraints/error) / # of trials \* 100  70 is chosen as the number of trials because:  “For normally distributed outcomes, the relative gain in precision of the pooled standard deviation is less than 10% (for each five subjects added per group) once the total sample size is 70” []  Alternatively, 60 trials are also acceptable as the source states that the sample size should be between 60-90 for the true size effect  → Testing the whole system, by making one of the follower sheep missing. (60 trials)  → Testing the whole system, by making one of the leader sheep missing. (60 trials?)  → Record the farthest detecting range of the Bluetooth RSSI, use this to calculate the minimum needed leader sheep percentage for 150 sheep assuming each sheep has an activity range of 2 meters and leader sheep are distributed evenly. (This is used for the validation) |
| Requirement | Far Tracking Range |
| Metric | Tracking range (m) |
| Criteria | Farther is preferred |
| Constraint | Must ≥ 2000 m. Should ≥ 2000 m |
| Testing | N/A |
| Note/Results? | Tracking range for leader sheep is infinite since GPS [find source maybe?],  Tracking range for follower sheep is infinite if immediate response is followed. Accuracy may be a different issue when there is significant time between moment of loss and attempt to find |
| Requirement | location accuracy |
| Metric | closeness of a measured location to the real location of the device at the time of measurement [12] (m) |
| Criteria | Closer is preferred. (GPS level accuracy is within 4.9m[13]). |
| Constraint | Must not exceed 500m because after testing, 500 m radius searching area makes a person tired. |
| Testing | N/A |
| Note/Results | 1. Location is GPS level accuracy for leader sheep: within ± 1m (Leader sheep, mobile phone GPS accuracy)  -> Do calculations: currently precise to 6 decimal places  → 5 trials, record the displacement and the GPS recorded, make a table? Or a plot? (build a calibration curve).  2. Location accuracy for follower sheep depends on cluster size, for 20% nodes, the average sheep cluster size is 5-10 making the location accuracy roughly be within one acre, 200m radius when the sheep wanders off [29]. The average sheep walking speed is 1.06m/s [30], and on average a sheep walks for 1 min and stops for 14 mins when wandering. Thus, the sheep will escape the updated cluster location by 254m/ hr. Thus, the location accuracy of the sheep would violate the constraint after 1-2 hours. If the sheep continuously walks, this time would be shortened to 5-8 minutes.  → Calculations from research  → Residual plot: plot the delay in time versus the predicted location uncertainty |
| Requirement | Signal Persistence |
| Metric | Pusle duration (s)  Pulse frequency (#/s) |
| Criteria | Longer pulse duration and more frequent the pulse is better [14] |
| Constraint | Must not be interrupted completely. |
| Testing | Research how persistent:  Bluetooth (frontend) + GPS signal persistence and GSM persistence (backend)  → emphasis GSM, justify why we believe the GSM works |
| Requirement | Signal Strength |
| Constraint | Should be easily perceptible to humans |
| Testing | Yes for this one cuz the warning message is easy to see from the computer. |
| Requirement | Uniqueness of Identification |
| Constraint | Must correctly differentiate each individual sheep among a group of sheep. |
| Testing | Binary results: O/X  → Collar printed each sheep’s id  → Customize the color to differentiate between owners |
| Source | [1] <https://en.wikipedia.org/wiki/Notification_system>  [2] Lahausse, J. A., Fildes, B. N., Page, Y., & Fitzharris, M. P. (2008). The potential for automatic crash notification systems to reduce road fatalities. *Annals of advances in automotive medicine. Association for the Advancement of Automotive Medicine. Annual Scientific Conference*, *52*, 85–92.  Refer to Design Proposal |

Accessibility

Sustainability

Durability

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| Requirement | Durability – Physical Collar + Battery |
| Metric | Lifetime of design to be 5 to 6 years [1]  Higher performance during tests is preferred |
| Criteria | Device needs to work for a long period without errors and mistakes.  Device needs to use for a long time without broken  Device can work against water and dust |
| Constraint | Past waterproof and dustproof test from IP5 to IP6[2] Past drop test for ANSI/ISEA 121-2018 [3] Working at least two weeks without charging [4] |
| Testing | Waterproof + Dustproof test:   * Sink device under water for 2 hours and check if functionality is the same [2]   + Put tissues inside the case and see if it soaks up any water   + Use rubber band to improve waterproof ability.   Drop test:   * “To perform the test, we statically load the product above its rated working limit and dynamically test above the rated working limit by attaching weights to the product with a rigid test setup and then dropping the weight.” [3] * Here, as the device will mostly be used in nature, sample objects that could drop are pebbles, rain, and sand * Since impacts of rain and sand will be dealt with in the waterproof/dustproof test above, dropping pebbles or objects of similar weight and getting note of the damage will suffice * To pass the test, no significant damage to the functionality or hardware should appear   → Think about possible scenarios that could damage the collar  → Research and thought experiment on possible materials we can use  Power test: Batter life time? (Ethan can do this research + calculations) |
| Source | [1] <https://www.iconcox.com/blog/how-long-does-the-gps-tracker-last.html>  [2] <https://atslab.com/environmental-testing/waterproof-testing/>  [3] <https://www.element.com/product-qualification-testing-services/dropped-objects-testing>  [4] <https://www.brickhousesecurity.com/gps-trackers/device-guide/> |

UNSDG, green materials

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| Requirement | Safety- Physical Collar |
| Criteria | Device needs to be safe to use around people and sheep |
| Metric 1  Metric 2 | Noise emitted in use (dB/frequency range)  A smaller stowaway volume is preferred (size) |
| Constraint | The typical hearing range of sheep is from 125 Hz to 40 kHz. Most sensitive at 7 kHz. The device must not operate in those frequencies [1].  Sheep can adapt to noise between 60-90dB. Device should not operate over 90dB [1]. |
| Testing | Through research, Bluetooth operates at 2.4GHz, so it is safe for the sheep, and will not cause harm. |
| Source | [1] <http://www.cvzv.sk/slju/14_2/8_Broucek.pdf> |
| Requirement | Electrical Safety – Physical Collar |
| Criteria | Device cannot cause harm through electrical discharge around people and sheep |
| Metric 1 | Operational voltage |
| Constraint | The operational voltage must not exceed 60V dc or 42.4 V\_peak ac. [1]. This comes from an international standard regarding the safety of handheld electronic devices. |
| Testing | Research, Electrical operation is between \_ and \_ for the arduino uno  The battery runs at 9V, so below the constraints.  → Looping wires, movements of the parts, exposed electrical components. |
| Source | [1] <https://webstore.iec.ch/preview/info_iec60950-1%7Bed2.0%7Den_d.pdf> |

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| Requirement | Portability – Physical Collar |
| Criteria | Device needs to be easy to move around, and shepherds must be able to use the device over the range of the grazing area (~5km through hilly terrain and villages). |
| Metric 1  Metric 2 | A lighter device is preferred (weight in pounds)  A smaller stowaway volume is preferred (size of dimensions in mm) |
| Constraint | Widget should be under 5.1 pounds if handheld.  → Weigh the collar  Widget should stow away to under 100x125x255mm in size.  → measure the collar  Both constraints come from the 2005 US human factors guide for the design of handheld devices. |
| Testing | Need to build the whole thing and weigh it. Since the device is not handheld we can find different standards for size... |
| Source | [1]<https://hf.tc.faa.gov/publications/2005-human-factors-guidance-for-the-use-of-handheld/full_text.pdf> |

In the future take note of:

Possible extreme cases:

When all leader sheep are grouped together, and all follower sheep are grouped together:

Could give false notifications, keep note of this in the future

Whole system testing:

## Update 1:

1. F1001 F1002 connects to the Ethan’s phone, ping both sheep get their IDs and get the GPS location of Ethan’s phone
2. Arielle manually concat the info into one string “\_LA = 27.12, LO = -73.12\_L1000F1001F1002” and send it to Emre’s laptop via Bluetooth
3. Emre run the sqlitedb.py file to write the info into database, then run the UI.py to display possible missing sheep infos (this case there is no missing sheep)

## Update 2 Missing Follower Sheep:

1. Make F1001 far away (out of the range set by RSSI = -55 dBm) connects to the Ethan’s phone, ping both sheep get their IDs and get the GPS location of Ethan’s phone
2. Arielle manually concat the info into one string “\_LA = 27.12, LO = -73.12\_L1000F1002” and send it to Emre’s laptop via Bluetooth
3. Sqlitedb.py should continuously listen to the message and write the new update to write the info into the database, UI.py should display possible missing sheep infos (missing F1001)

## Update 3 Missing Leader Sheep:

1. Make F1002 far away as well (out of the range set by RSSI = -55 dBm) connects to the Ethan’s phone, ping both sheep get their IDs and get the GPS location of Ethan’s phone
2. Arielle manually concat the info into one string “\_LA = 27.12, LO = -73.12\_L1000” and send it to Emre’s laptop via Bluetooth
3. Sqlitedb.py should continuously listen to the message and write the new update to write the info into the database, UI.py should display possible missing sheep infos (missing F1000)