

FAIMS Mobile: Flexible, open-source software for field research

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Abstract

FAIMS Mobile is a native Android application supported by an Ubuntu server facilitating human-mediated field research across disciplines. It consists of ‘core’ Java and Ruby software providing a platform for data capture, which can be deeply customised using ‘definition packets’ consisting of XML documents (data schema and UI) and Beanshell scripts (automation). Definition packets can be generated using an XML-based domain specific language. FAIMS Mobile includes features allowing rich and efficient data capture tailored to the needs of fieldwork. It also promotes synthetic research and improves transparency and reproducibility through the production of comprehensive datasets that can be mapped to vocabularies or ontologies as they are created.

Keywords: Android, Mobile software, Field research, Field Science

¹ 1. Motivation and significance

² Many disciplines in the social sciences, humanities, and biological, earth,
³ and environmental sciences depend upon data generated through human-
⁴ mediated fieldwork. Such data might arise from excavation in archaeology,
⁵ wildlife observation in ecology, soil sampling in environmental geochemistry,
⁶ or subject interviews in oral history. Field research disciplines, however, often

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7 lack transparency and reproducibility, compromising the integrity of research
8 results [1]. Field data is often collected using an ad-hoc mix of hard copy, data
9 fragments in various formats, and bespoke databases [2, 3, 4, 5]. Datasets,
10 furthermore, are often trapped in hard-copy archives, local storage, or digital
11 ‘silos’, making them difficult to discover and limiting reinterpretation and
12 reuse [6]. Digital datasets are often highly variable, of poor quality, and
13 incompatible. Deficiencies like these inhibit re-analyses of primary data and
14 the combination of datasets from multiple studies for large-scale research
15 [4, 7, 1].

16 Insufficient attention has been paid to the development of software specif-
17 ically designed for digital data collection during field research. Some tools
18 exist for discrete tasks, such as measuring strikes and dips for structural
19 geology (e.g., GeoCline or Rocklogger for Android), but more complex and
20 flexible field data collection has been neglected. Most digital data collection
21 in archaeology, for example, is accomplished either using a combination of
22 generic and repurposed mobile and desktop applications (e.g., multimedia,
23 office productivity, GIS, database, or questionnaire / survey software), or by
24 building bespoke applications. Both approaches have severe limitations [8].
25 Bespoke software is expensive to build and maintain, placing it beyond the
26 reach of all but the best-funded projects and organisations (e.g., iDig, created
27 by the American School of Classical Studies at Athens: <http://idig.tips/>
28 (Archived at: <https://perma.cc/23PS-6567>); [9]). Repurposed software
29 requires field researchers to make do with applications, designed for other
30 contexts, which lack critical features but still require extensive customisa-
31 tion (cf. the use of a suite of iOS applications at Pompeii [10], or Ben
32 Carter’s combination of Kobo Toolbox, PostGIS, QGIS, LibreOffice Base,
33 and pgadminIII [11]).

34 FAIMS Mobile, conversely, is ‘generalised’ software which combines the
35 particular features required for field research with sufficient customisabil-
36 ity and redeployability to allow its use across disciplines, providing a large
37 enough user base to support its development and maintenance and have a
38 meaningful impact on research (see Section 4 below; cf. [8]). FAIMS Mobile
39 is open source software developed by the Field Acquired Information Systems
40 Project, an e-research infrastructure project based at Macquarie University,
41 Sydney, Australia. It is mature software that has been under development
42 since 2012 (see: [12, 13, 14]). Most other generalised field data collection
43 software used for fieldwork, such as ARK, Heurist, or Kora [15], requires a
44 continuous connection to a server.

45 FAIMS is most comparable to Open Data Kit (ODK) and its variants,
46 but is differentiated by its lineage. ODK, another mature offline mobile data
47 collection platform, was designed for social surveys, where an investigator

48 asks questions of a interviewee. FAIMS, conversely, originated in archaeology,
49 where an investigator records observations about things in the material world,
50 relationships between those observations, and metadata contextualising the
51 collection of those observations. Both projects are open-source, Java-based
52 data collection platforms with similar potential and shared libraries, serving
53 researchers who face similar problems; while solutions to those problems
54 diverged significantly when FAIMS began development, over time features
55 have converged to a degree. Features specific to FAIMS include mature
56 bi-directional synchronisation across all devices (an alpha feature in ODK
57 2.0), use of an append-only datastore that provides a version history for all
58 records, support for a wider range of external sensors, and more advanced GIS
59 data operations (compared to GeoODK). Provisions for help and metadata
60 capture are also richer and more granular. Field research projects, especially
61 in liminal disciplines such as linguistics or oral history, would be wise to
62 evaluate both platforms.

63 *1.1. Experimental setting*

64 FAIMS Mobile is designed to collect heterogenous data of various types
65 (structured, free text, geospatial, multimedia) produced by arbitrary method-
66 ologies during human-mediated field research. It requires customisation to
67 instantiate a project-specific data model, user interface, and workflow, but
68 it addresses problems shared across field-based projects, such as provision
69 of a mobile GIS and automated synchronisation across multiple devices in a
70 network-degraded environment.

71 During a typical deployment, researchers work with FAIMS project staff
72 to articulate their data model and workflow. A FAIMS developer then ren-
73 ders that methodology into a ‘definition packet’ of files that produce a ‘mod-
74 ule’ (i.e., an implementation of FAIMS Mobile customised for a particular
75 project). Separate definition packet files control the data schema (XML),
76 the user interface (XML and CSS), and automation and logic (Beanshell),
77 offering nuanced control. The interface can also be translated into multiple
78 languages using a (plain text) localisation file. Completed modules are then
79 deployed to a local or online Ubuntu server, and from there onto as many
80 Android devices as needed (after the core mobile application is installed,
81 e.g. from Google Play). Data is then collected using those devices, which
82 can operate fully offline, and synchronised opportunistically when a network
83 connection to the server is available. Data can be validated at the time of
84 entry on the device, or later on the server. At the end of data collection,
85 data is exported in the user’s desired format by means of a customisable
86 exporter. Three deployment case studies have been published in Sobotkova,
87 et al., 2016[8].

88 Alternatively, FAIMS has developed a XML-based domain specific language (DSL) to simplify customisation. Using this DSL, a single file can
89 be used to generate all necessary definition packet files. In addition to de-
90 ployments conducted by the FAIMS team, projects have independently cus-
91 tomised FAIMS Mobile themselves using both approaches [16, 17].

93 **2. Software description**

94 FAIMS Mobile is open-source, customisable software designed specifically
95 to support field research across many domains. It allows offline collection
96 of structured, text, multimedia, and geospatial data on multiple Android
97 devices, and is built around an append-only datastore that provides complete
98 version histories. It includes customisable export to existing databases or in
99 standard formats, supported by features that facilitate data compatibility.
100 Finally, it is designed for rapid prototyping using and easy redeployability to
101 reduce the costs of implementation.

102 *2.1. Software Architecture*

103 FAIMS Mobile consists of ‘core’ software written in Java and Ruby, cus-
104 tomised to particular field deployments using reusable and sharable definition
105 packets consisting of XML, Beanshell, and CSS files (or, by sacrificing some
106 nuances of control, a single file written in a DSL). More specifically, FAIMS
107 uses the following technologies:

- 108 • Javarosa to render native Android UI elements at runtime;
- 109 • Sqlite3 to store an attribute-key-value datastore (with data schemas
110 definable at runtime);
- 111 • An append-only data model inspired by Google’s Protobufs;
- 112 • Beanshell to provide runtime scripting via calls to an underlying Java
113 API;
- 114 • Spatialite to encode geospatial data in the datastore;
- 115 • Nutiteq to render geospatial data;
- 116 • NativeCSS to style android-native elements;
- 117 • Antlr3 as a grammar parser for identifiers; and a
- 118 • Ruby on rails/Apache stack to provide a server, which can be hosted
119 online or on modest hardware in the field.

120 We developed this architecture to meet two fundamental requirements:
121 (1) the software had to accommodate a wide range of research designs, data
122 schemas, and workflows, and (2) the software had to accommodate extremely
123 variable structured, free text, multimedia, and geospatial data. Essentially,
124 we needed to build a system capable of rendering and recording arbitrary
125 field data, since individual ‘data loggers’ tied to a particular methodologies
126 (even if extensible) would not be worth the investment to build and deploy
127 as separate mobile applications.

128 Our Android client can, at runtime, render an arbitrary data collection
129 methodology (schema and workflow), save all records to a datastore, and
130 opportunistically synchronize that data with instances of the software run-
131 ning on other devices. This distinction is much like the one between a web
132 browser and a website. A browser contains many sophisticated engines for
133 rendering the page, its interactivity, and its styling, but does not have con-
134 tent. A website uses the HTML engine provided by the browser to display
135 its specific content. FAIMS Mobile likewise provides engines for rendering
136 definition packets to produce customised data collection modules.

137 Four years of deployment experience revealed the importance of quality
138 assurance, something too often neglected in academic software [18, 19]. Each
139 customisation and deployment is, indeed, a miniature software development
140 project [8]. Due to the need for significant QA per deployment, FAIMS Mo-
141 bile 2.5 supports Robotium for unit and integration tests on customised data
142 collection modules, such that large amounts of test data can be automati-
143 cally added via the normal user interface. This allows users to load test their
144 modules under simulated field conditions.

145 *2.2. Software Functionalities*

146 FAIMS Mobile improves field research by providing a wide range of fea-
147 tures that specifically address the needs of field research across disciplines,
148 while facilitating the production of compatible datasets from heterogeneous
149 data structures and workflows. These features include:

- 150 • Deep customisation of data schema, user interface, and automation us-
151 ing either a packet of XML, Beanshell, and CSS documents for nuanced
152 control, or a single file in an XML-based domain-specific language for
153 ease of deployment. Definition document(s) are separate for core soft-
154 ware, making modification and reuse easier.
- 155 • Collection of various data types within a single record, including struc-
156 tured data, geospatial data, free text, sensor-produced multimedia, and
157 file attachments.

- 158 ● Automated, configurable synchronisation across an unlimited number
159 of devices using a local or online server.
- 160 ● Synchronisation is opportunistic, whenever a connection is available, al-
161 lowing devices to work in network-degraded environments or offline for
162 extended periods of time. Robust offline capability is achieved through
163 maintenance of the datastore on each device, not caching.
- 164 ● Defaults, flow logic, hierarchical selections, dynamic UI (expand, col-
165 lapse, hide, or show input fields), and other advanced data collection
166 features.
- 167 ● Mobile GIS supporting raster and vector data, layer management, legacy
168 data visualisation, and point, line, and polygon creation and editing.
169 Multiple records can be linked to a single shape, or multiple shapes to
170 a single record.
- 171 ● ‘Annotation’ and ‘certainty’ fields attached to every record. The former
172 allows the collection of granular metadata (mimicking the ‘margins of
173 the page’ in paper recording), while the latter allows users to record
174 their confidence in an observation.
- 175 ● Internal and external sensor support, external Bluetooth devices like
176 GPS receivers and USB / HID devices like digital balances and calipers.
- 177 ● Multilingual support using a localisation file.
- 178 ● An append-only datastore providing a full revision history, including
179 the ability to review and reverse changes selectively.
- 180 ● Mobile device and server-side validation.
- 181 ● Aids to good practice including contextual HTML help, ‘picture dictio-
182 naries’ (selections based on images), and selection trees that can guide
183 users through complex processes.
- 184 ● Embedding of URIs into controlled vocabularies or other elements to
185 link them to shared vocabularies, thesauri, or ontologies.
- 186 ● Customisable export to desktop software, pre-existing databases, or
187 online data services (based on SQL queries).

188 2.3. Sample code snippets analysis

189 While a thorough discussion of the module code is out of scope for this
 190 paper, we have two fundamental documents which discuss module creation
 191 from start to finish. The first: ‘FAIMS User to Developer Documentation’
 192 (linked at <https://www.fedarch.org/support/#2>, archived at: <https://perma.cc/8JDY-6RKL>) is designed to walk normal users through the creation
 193 of a module from first principles. The second ‘The FAIMS Cookbook’ is
 194 a description of our data structures and API designed in a rough tutorial
 195 format (linked: from support page above, archived: <https://perma.cc/H6XJ-X6E2>).
 197

198 3. Illustrative Examples

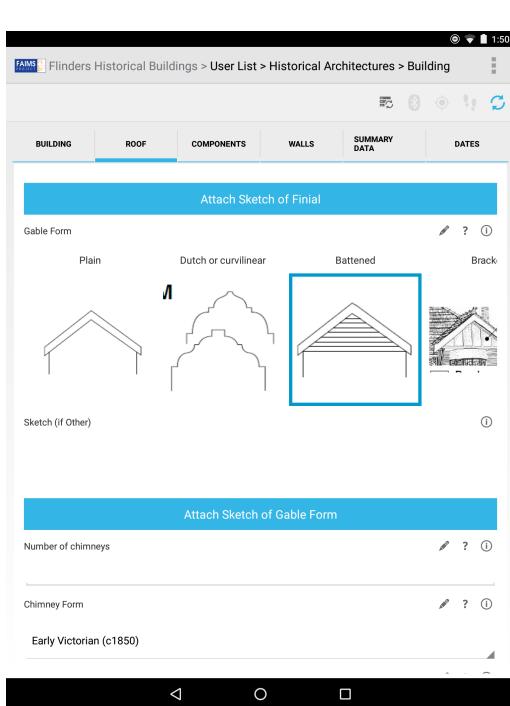


Figure 1: Structured data recording: including dropdowns, numeric fields, checkboxes, radio buttons, and ‘picture dictionaries’

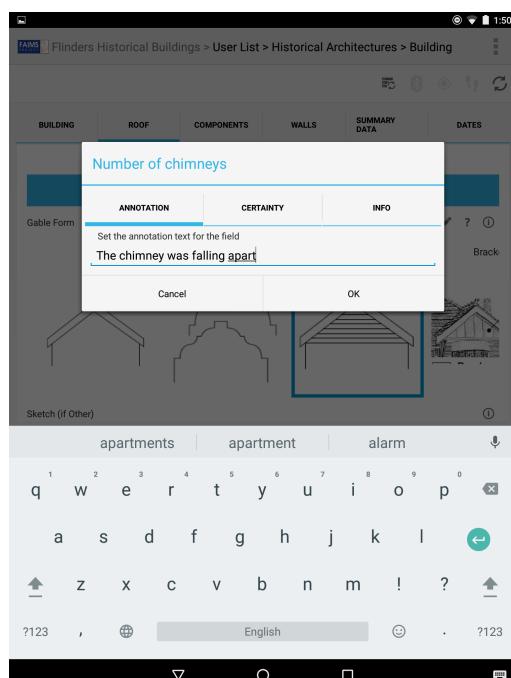


Figure 2: FAIMS has metadata such as annotations (digital ‘scribbling on the margin’) and certainty. Granular, contextualised, HTML-format help (‘info’) is also delivered using this interface

199 FAIMS offers a variety of ways to record data (Fig. 1) all of which can be
 200 arranged hierarchically. Each of the fields, regardless of datatype, also allows
 201 for the recording of metadata (Fig. 2).

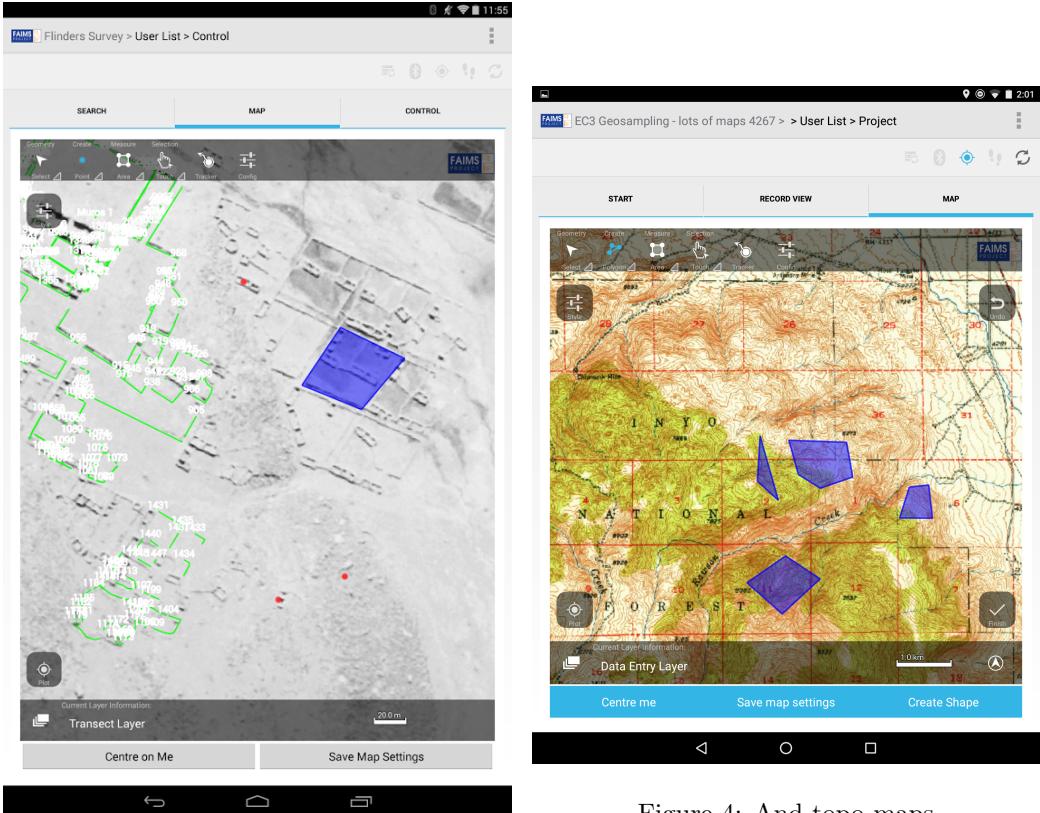


Figure 4: And topo maps

Figure 3: FAIMS Mobile can render layers of georeferenced raster files like satellite images

202 Field research often requires spatial data capture and visualisation. FAIMS
 203 has GIS rendering capabilities for rasters (Figs. 3, 4), or vector data (blue
 204 polygons in both). Vector data can be created in the field and automatically
 205 bound to a record. Currently, most survey modules use mobile GIS
 206 functionality.

207 4. Impact

208 FAIMS allows the efficient collection of field data, dramatically reducing
 209 or eliminating manual digitisation (see [8]). Near-real-time availability of
 210 data from multiple devices for review also provides immediate error detection
 211 (especially when combined with validation and contextual help). Finally, the
 212 software is customisable, extensible, and community driven; if current or po-
 213 tential users request new features, they can be implemented (within budget
 214 constraints). Field research will never represent more than a fraction of the
 215 market for generic, mass-market products, whereas it is the sole focus of

216 FAIMS. Researchers can, therefore, compromise less and actively contribute
217 to the development of purpose-built software through their specific customi-
218 sations or core-software feature requests [8]. Organisations with sufficient
219 development capacity are, of course, also welcome to contribute to the core
220 software open source project.

221 Beyond the immediate needs of users, FAIMS Mobile improves research
222 practice and data management. URIs can be embedded in controlled vocab-
223 uaries and other elements[14], linking them to linked open data sources (e.g.,
224 species information can be linked to the Encyclopedia of Life[20]). Localisa-
225 tion can be used to ‘translate’ a local language of practice to a standard
226 vocabulary (e.g., ‘context’ or ‘locus’ can be translated to ‘statigraphic unit’
227 - and then linked to an online ontology). Customisable data export for-
228 mats collected data for existing services or standards (e.g., archaeological
229 records can be exported not only as shapefiles, CSVs, or a 3NF relational
230 database for incorporation into an existing geodatabase, but also as XML
231 or GeoJSON for ingest into domain-specific repositories like Open Context).
232 Perhaps most importantly, comprehensive, rather than selective, datasets can
233 be created and exported for publication, improving transparency and repro-
234 ducibility. Combined with features that improve data compatibility across
235 projects, FAIMS assists large-scale field research.

236 FAIMS Mobile also makes digital recording a more feasible and less costly
237 option for researchers [8, 14]. The core software does the ‘heavy lifting’ of
238 field recording (data storage, bi-directional synchronisation, GIS, etc.), and
239 can be customised by either leveraging the control of a full definition packet
240 or the efficiency of the single-file DSL module generator. An experienced
241 developer can rapidly prototype a recording system /so long as data and
242 workflow models are available (well-scoped field recording systems of mod-
243 erate complexity can be prototyped in one to two developer-days). Reuse
244 and modification of existing customisations from a growing, openly-licensed
245 online library (leveraging version control systems like GitHub) also helps to
246 reduce deployment costs[12]. Deployment of FAIMS Mobile is therefore less
247 expensive than production of bespoke mobile applications, and competitive
248 with deployment of a suite of generic tools with many different features: a
249 geoDBMS, GIS, social survey software, multimedia management software,
250 note-taking software, etc. [11]. FAIMS sacrifices the ultimate flexibility of
251 these generic tools to offer more functionality specific to field research, better
252 integration of different data types, and fewer compromises on the part of the
253 researcher. Since FAIMS is also easier to redeploy than customised combi-
254 nations of mass-market software, it allows improvements and innovations to
255 be shared more readily[12].

256 FAIMS Mobile has changed users’ daily practice. Three case studies in-

volving archaeological deployments [8] indicate that users benefit from the increased efficiency of fieldwork, in that the time saved by avoiding digitisation more than offsets the time required to implement FAIMS and more data collected during fieldwork of a given length. Born-digital data avoided problems with delayed digitisation, which often occurred long after field recording when the context of the record had been forgotten (or the person making the record was no longer available). Researchers reported more complete, consistent, and granular data. They also reported that information could be exchanged more quickly between excavators and specialists, which in one case improved ‘post-excavation reconstruction of the site’ and facilitated the evaluation of patterns for meaning in another. They also observed that the process of moving from paper to digital required comprehensive reviews of field practice, during which knowledge implicit in existing systems to become explicit and data was modelled more carefully. By participating in a ‘miniature software development project’, researchers gained familiarity with the strengths, limits, and demands of software deployment, especially the need for extensive testing. The greatest challenge posed by the transition from paper has been the reallocation of time from the end of a project (digitisation) to the beginning (data modelling, development, and testing), even if they realise an overall time savings.

Although adoption of digital recording during fieldwork represents a significant socio-technical change, FAIMS Mobile has seen good uptake. Since 2012 FAIMS Mobile has supported over 25 major research projects, with approximately 300 users logging over 10,000 hours in the application. Most uptake to date has been at large, multi-year projects that are still early in their lifecycle, so all FAIMS-related publications to date have focused on the software itself or the transition from paper-based to digital workflows. While archaeologists comprise the main user group, FAIMS now supports research in other disciplines as well. Fifteen archaeology, ecology, and history projects are scheduled for 2017 with an estimated usage of 12,000 hours. A 2016-2017 New South Wales Research Attraction and Acceleration Program award is funding links to government resources (e.g., automated data submission to the Aboriginal Heritage Information Management System of NSW) making it more attractive to commercial users. This award is also funding community-based heritage and science deployments, where members of the public will be able to download preconfigured versions of FAIMS Mobile to report information about archaeological remains or wildlife.

294 **5. Conclusions**

295 When they collect data digitally, field researchers often re-purpose mass-
296 market or general-purpose software that was not specifically designed to meet
297 their needs, often requiring several pieces of software (some of which are indi-
298 vidually complex) to accommodate the rich and varied data they must collect.
299 FAIMS Mobile offers an alternative. It is purpose-built for field research with
300 extensive community input, including five years of iterative co-development
301 with field researchers first in archaeology, and more recently in geoscience,
302 history, and ecology. FAIMS Mobile offers an unparalleled range of features
303 to support fieldwork, including collection of structured, free-text, multi-
304 media, and geospatial data, deep customisability, mobile GIS, use of internal
305 and external sensors, offline capability with opportunistic synchronisation
306 using either an online or local server, full record version histories, multilin-
307 gual support, certainties and annotations attached to individual fields, and
308 rich contextual help. It includes customisable export to existing databases
309 or in standard formats, supported by features that facilitate data compati-
310 bility. It is designed for rapid prototyping and easy redeployability to reduce
311 the costs of implementation, leveraging community software version control
312 systems like GitHub. FAIMS Mobile is community-driven, customisable, ex-
313 tensible software that can support the socio-technical transition from paper
314 to digital in field research disciplines and facilitate the production of com-
315 prehensive, compatible datasets to improve synthetic research, transparency,
316 and reproducibility.

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409 77–80.

410 **Required Metadata**

Nr.	Code metadata description	Please fill in this column
C1	Current code version	2.5
C2	Permanent link to code/repository used for this code version	<p>Core Application https://github.com/FAIMS/faims-android</p> <p>Server https://github.com/FAIMS/faims-web</p> <p>Definition Packets https://github.com/FAIMS</p>
C3	Legal Code License	GPLv3
C4	Code versioning system used	git
C5	Software code languages, tools, and services used	Java, Ruby, XML, SQLite, Spatialite, Javarosa, Antlr, Puppet, Apache, Imagemagick, God, Beanshell, gson, guice, Nutiteq (non-free), NativeCSS, Protobuf, Robotium
C6	Compilation requirements, operating environments & dependencies	Android Studio, Ubuntu 16.04, Nutiteq license (for non-watermarked GIS)
C7	If available Link to developer documentation/manual	<p>Module Cookbook https://faimsproject.atlassian.net/wiki/display/FAIMS/FAIMS+Data%2C+UI+and+Logic+Cook-Book</p> <p>Module Beanshell API https://faimsproject.atlassian.net/wiki/display/FAIMS/Program+Logic+Support</p> <p>Developer documentation home https://faimsproject.atlassian.net/wiki/spaces/FAIMS/overview</p> <p>'User to developer' documentation https://www.fedarch.org/support/</p>
C8	Support email for questions	support@fedarch.org

Nr.	(Executable) software meta-data description	Please fill in this column
S1	Current software version	2.5.20
S2	Permanent link to executables of this version	<p>FAIMS Mobile http://www.fedarch.org/apk/</p> <p>Google Play https://play.google.com/store/apps/details?id=au.edu.faims.mq.fieldresearch2&hl=en</p> <p>Server Installer (wget and pipe to bash) https://raw.githubusercontent.com/FAIMS/faims-web/master/installer/puppetInstall.sh</p>
S3	Legal Software License	GPLv3
S4	Computing platforms/Operating Systems	Android, Ubuntu
S5	Installation requirements & dependencies	Android 6+, Ubuntu 16.04
S6	If available, link to user manual - if formally published include a reference to the publication in the reference list	'Getting started' guide and user documentation: https://faimsproject.atlassian.net/wiki/display/FAIMS/Getting+started+with+FAIMS+-+an+overview
S7	Support email for questions	support@fedarch.org

Table .2: Software metadata (optional)