From Arctic UAS Reconnaissance to Planetary Rotorcraft Science

An evidence tracking workflow for linking aerial observations with ground investigation at FMARS

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Declarations

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Abstract

Aerial reconnaissance can place a ground target within its terrain context, but scientific interpretation requires a traceable connection between the image, its processing history, and the field record. This technical case study describes an evidence tracking workflow for imagery associated with the Flashline Mars Arctic Research Station on Devon Island, Canada. The available sources include 1,141 original aerial photographs with July 2026 camera timestamps and a separate ground video filmed by Trevor Jahn in July 2025. Selected aerial photographs show the habitat, tracks, snow patches, and snow-lined channel margins. A worked example records a deliberately selected pixel in an original photograph, preserves the source identity and observation, and exports a record with no geographic geometry because a ground position has not been established. This demonstrates image-space traceability without converting camera GPS into a ground coordinate. The ground video supplies a separate outcrop perspective whose correspondence with the aerial coverage remains unresolved. Reconstruction products are retained as context pending documentation of processing and geometric validation. The case defines the additional site, timing, calibration, and uncertainty information needed before integrating environmental measurements. Its contribution to planetary rotorcraft science is a practical record structure for connecting aerial target selection with surface verification. It reports a documentation example and validation protocol, not measured runoff, confirmed mineral composition, or an assessment of reconstruction accuracy.

Keywords: UAS; FMARS; Arctic analogue; photogrammetry; image provenance; planetary rotorcraft; ground validation

Introduction

Aerial reconnaissance changes the context in which a field scientist chooses a place to investigate. An overhead view can place a snow patch, track, or outcrop within surrounding terrain, whereas a ground visit can inspect surface properties that the overhead image cannot resolve. The scientific value depends on maintaining the connection between those views. If location, acquisition time, processing history, or spatial support is lost, an attractive image can encourage an interpretation that the available evidence cannot test.

Structure from motion estimates camera poses and scene geometry from overlapping photographs and has established uses in geoscience (Westoby et al., 2012). Its products nevertheless require validation: image networks and camera calibration can introduce systematic topographic error (James and Robson, 2014). These considerations motivate a distinction between what a photograph records, what reconstruction estimates, and what independent measurements establish.

This paper develops that distinction around a field imagery collection associated with the Flashline Mars Arctic Research Station (FMARS), on Devon Island in the Canadian Arctic. It expands AGU26 abstract 2089569, “From Arctic UAS Reconnaissance to Planetary Rotorcraft Science: Linking Aerial Observations with Ground Measurements,” accepted for session EP43F on 10 December 2026. The case combines a source inventory, qualitative image review, and an image-space target record. The aerial and ground campaigns remain separate until their geographic correspondence can be established.

The objective is to define a traceable path from source imagery to a testable ground question. The contribution consists of a documented source inventory, a descriptive imagery case study, and an explicit target record and validation protocol. No new photogrammetric reconstruction, accuracy benchmark, hydrological measurement, mineral analysis, or biological result is reported.

Field context and scientific scope

FMARS and the neighboring Haughton Mars Project (HMP) are distinct facilities. The round habitat shown in Figure 1 identifies FMARS; a reconstruction or regional view extending toward HMP should not be labeled as FMARS infrastructure throughout its footprint. The geographic extent and registration of each derived product must be established separately from facility identification.

Haughton has a documented history of impact-related hydrothermal alteration (Osinski et al., 2005). That regional background provides a reason to investigate mineral-rich exposures, but it does not identify the composition, origin, or activity of the particular outcrop in the supplied video. In this manuscript, “gossan locality” records the author’s field identification and remains unverified by coordinates or mineralogical measurements.

The terrestrial case is relevant to planetary exploration through the sequence of reconnaissance, target choice, and local testing. The analogy concerns the management of evidence and operational decisions. It does not assume that the Arctic site reproduces Martian or Titanian atmospheric conditions, surface chemistry, or biological potential.

Materials and provenance

The local inventory contains 1,141 original JPG photographs, all 4000 × 3000 pixels, with the camera model field recorded as M3T. The earliest and latest inventory timestamps are 10 July 2026 at 11:16:58 and 11 July 2026 at 15:22:30. These are camera metadata times; their timezone and absolute clock accuracy have not been confirmed. The inventory count describes available files, not independent field samples, mapped area, or the number of flight missions.

Rhett Woods acquired the aerial imagery. In correspondence supplied by the author, he reported a flight height of 300 ft above the habitat takeoff elevation, nominal front and side overlaps of 75% and 65%, speeds of 8–10 m/s, a wide RGB camera, and distance-based image triggering. The trigger interval was not supplied. His estimated ground sampling distances were approximately 2.5 cm per pixel near the habitat and 3–3.5 cm per pixel in the lower gully. These settings and

estimates have not been independently reconstructed from flight logs, and their applicability to every file remains to be checked. Height above takeoff does not establish constant height above terrain.

A model published by Tash Coelho uses Rhett's imagery, according to the supplied project correspondence. A separate screenshot shows an oblique reconstructed terrain surface with purple line overlays. The screenshot's precise source, processing software, software version, coordinate system, scale, and overlay meaning are unresolved. It is retained as context rather than used as a measurement surface. An earlier Vimeo folder supplied for processed footage is unavailable; no comparison in this study depends on recovering it.

The ground source is VID_20221212_141837_10_028_gossan_neearby.insv. Despite its filename, the author confirmed that Trevor Jahn filmed it in July 2025 and that the camera date was wrong. The exact capture day and site coordinates remain unknown. The inspected decoded stream contains 1,500 frames at 24 frames per second, with a 2880 × 2880 pixel frame size and a nominal duration of 62.5 s. These properties describe the stream opened for review, not a verification of every component or sensor stream in the native container.

Methods for source review and evidence tracking

The original aerial files were inventoried with a Python preparation routine that records filename, path, file size, pixel dimensions, camera model, and available capture time. Contact sheets supported visual screening, followed by inspection of selected views at higher resolution. The examples in Figures 1 and 2 were selected to illustrate facility identity and snow or channel context. Selection was qualitative and purposive; it was not a randomized sampling design, a complete feature census, or a reproducibility test between independent interpreters.

A separate Python routine decoded the video with OpenCV and attempted evenly spaced review frames. Eleven frames were retained with source frame indices and time offsets in a manifest. Figure 3 uses frame 818, nominally 34.08 s into the decoded stream. Review images preserve the decoded lens projection. No synthetic completion, generative enhancement, mineral classification, or calibrated dewarping was applied. Figure display resizing preserves aspect ratio. Projection distortion precludes treating apparent shapes or distances as corrected ground geometry.

The review distinguishes five evidence states. A source record describes a file or metadata value. An image observation describes visible content without a causal explanation. A reported attribute preserves a contributor's statement with its source. An interpretation proposes a process or material identity. A validated measurement would require a documented method, units, calibration, and uncertainty. The present case includes the first four states but no validated environmental or reconstruction measurements.

The companion website implements image-space target selection. A pin retains the original filename and pixel coordinates. Optional WGS84 coordinates require a separately entered source. Camera GPS is identified as the aircraft position, not the ground position of a selected pixel. Photo-only records export without a geographic geometry. These controls preserve the distinction between an image location and a surveyed site; they do not perform photogrammetric geolocation. Saved records remain in the visitor's browser unless exported.

For a future linked record, the proposed minimum fields are a persistent site identifier; source file and frame or pixel location; acquisition date and time basis; geographic coordinates with reference system, datum where applicable, and method; spatial support of the observation; observation or

measurement with units; calibration and uncertainty; processing history; and evidence state. Table 1 summarizes the decisions these fields support. Record completeness is a prerequisite for integration, not a substitute for checking whether the match is correct.

Table 1 Minimum evidence record and its use

Record group	Decision supported
Source identity	Recover the exact photograph or video frame and its processing lineage.
Image location	Return to the same original-image pixel without assuming a ground coordinate.
Geographic and temporal match	Decide whether the ground and aerial observations concern the same feature and comparable conditions.
Measurement method and uncertainty	Judge whether a value supports a comparison at the required scale.
Evidence state	Separate a direct observation, contributor report, interpretation, and validated measurement.

Descriptive observations

The selected overhead habitat photograph shows the round FMARS structure, surrounding rocky ground, equipment, and tracks (Figure 1). This is sufficient for facility context and for choosing recognizable features for a later comparison. It provides no independently surveyed reference dimensions in this analysis. Objects of familiar appearance can help locate a possible mismatch, but remembered or assumed dimensions should not be used as calibration measurements.

The aerial terrain examples show patches or bands of snow beside exposed ground, branching linear surface traces, and vehicle tracks (Figure 2). Their visibility supports candidate questions about the relationships among snow margins, channel geometry, and routes. A single visible pattern does not establish contemporary water flow, flow direction, discharge, erosion rate, or a change in the landscape. The present review has neither delineated a catchment nor measured a channel cross section.

The ground video shows people near a rocky exposure and later closer views of surfaces with color and texture variation (Figure 3). Its closer perspective could support a future comparison with field notes or specimens. Color variation alone cannot establish specific minerals, microbial communities, oxidation pathways, or the origin of the exposure. The retained review frames do not establish active boiling. No quantitative scale is assigned to the image.

A wider reconstructed view can organize terrain visually, but the supplied screenshot does not provide a documented correspondence with the selected aerial photographs or the ground outcrop. The 2025 and 2026 sources therefore remain separate campaigns. The available material supports a candidate investigation workflow and contextual illustrations; it does not demonstrate a repeated visit to the same surveyed feature or a measured change between years.

Worked example of an image space target record

To demonstrate the record structure, an image-center point was selected in DJI_20260710112011_0040_V.JPG during manuscript preparation on 11 November 2026. The point is at zero-based pixel coordinates x = 2000 and y = 1500 in the original 4000 × 3000 pixel photograph, with the origin at the upper left. It is a documentation example, not a field sampling location or a surveyed feature boundary. The capture timestamp remains 10 July 2026 at 11:20:11 by camera metadata.

The observation recorded for this point is exposed ground between visible snow bands, as illustrated by the lower panel of Figure 2. An associated field question asks whether the ground is wet during a matched visit and whether surface water is continuous along the corridor. That question remains untested. The record does not assign a water level, a flow direction, or a material composition.

Table 2 reproduces the principal fields of the accompanying JSON record. Its geographic geometry is explicitly null, and no aircraft GPS value is substituted for a target position. The record allows another reader to recover the source image and selected pixel while preserving the unresolved geographic match. This demonstrates source-to-record traceability; it is not an accuracy or usability evaluation of the website.

Table 2 Worked example record DEMO 0040 CENTER

Field	Recorded value
Record kind	Manuscript preparation demonstration, not a field sample
Source image	DJI_20260710112011_0040_V.JPG
Capture time	10 July 2026 11:20:11 by camera metadata; timezone unconfirmed
Image location	x = 2000, y = 1500; zero based; original 4000 × 3000 pixels
Selection date	11 November 2026 during manuscript preparation
Observation	Exposed ground between visible snow bands
Ground question	Wetness and surface-water continuity during a matched field visit
Geographic geometry	null; no ground coordinates assigned
Measurement	null; no environmental measurement supplied

Validation protocol

Geographic validation should begin with field records, flight logs, and the model’s coordinate reference system. A ground photograph, a target pin in an unregistered image, and the aircraft GPS position must remain separate records until an explicit transformation or independently recognizable correspondence connects them. Any later orthomosaic or elevation model should include its reference system and vertical datum, processing configuration, and a description of control and independent checkpoints. Checkpoints used to assess accuracy should not also be treated as independent if they constrained the solution.

Reconstruction review should compare source photographs, camera coverage, mesh geometry, and texture separately. A suspected habitat mismatch raised in project correspondence is a question for this review, not an established defect or evidence of a particular software behavior. Missing views, weak geometric constraints, texture projection, interpolation, and other processing choices are possible topics to examine; none has been diagnosed for the supplied model. A useful comparison would identify a feature visible in several source views, inspect the corresponding model geometry, and test it against an independent reference.

Estimated ground sampling distance describes image sampling. It does not establish horizontal or vertical accuracy, minimum detectable change, or the reliability of an inferred ground position. The reported centimeter-scale pixel sizes should consequently remain acquisition context until a validated processing and accuracy assessment relates them to the intended measurement. No numeric error threshold or minimum detectable change is assigned here.

An environmental test must match the observation to the phenomenon and its timescale. A question about runoff could use dated ground images, observations of water presence, repeat surveys, and measured channel geometry. A question about material composition would require specimens or suitable analytical measurements with documented provenance. Temperature, pH, electrical conductivity, or biological observations may be relevant if actually collected, but no such values are available for analysis in this manuscript. The protocol is prospective.

Software terminology alone cannot determine the role of machine learning. A conventional structure-from-motion pipeline may coexist with other processing stages, and a reconstructed visual product does not reveal which stages were used. The model's use of machine learning remains unclassified until software versions, settings, and documentation are available. Irrespective of implementation, any estimated or completed geometry must be distinguished from directly supported surface observations when evaluating a scientific claim.

Discussion and planetary implications

The central operational issue is the point at which a visual impression becomes a decision to visit, sample, or measure. A target record makes that transition inspectable. A scientist can record a visible snow boundary, state a question about it, identify what independent evidence would address the question, and preserve unresolved location or timing uncertainty. A record with missing coordinates can still be useful for organizing a photograph, provided it does not silently become a geographic measurement.

This approach can make a negative or incomplete result explicit. Failure to match an outcrop to an aerial footprint is a limit on the comparison, rather than evidence of absence of the feature. Similarly, an unavailable processing history prevents an accuracy claim but does not erase the original photographic observations. Preserving those distinctions allows later field records or a documented reconstruction to improve a target without rewriting the history of its interpretation.

Ingenuity's use as an aerial scout for Perseverance provides a mission example of aerial information informing surface operations (NASA, n.d.-a). Dragonfly is designed to investigate Titan through visits to multiple geological settings and local sampling and measurements (NASA, n.d.-b). These examples motivate the relevance of a documented connection between reconnaissance and local investigation. They do not validate the FMARS workflow or demonstrate that the same instruments, navigation methods, or decision thresholds will transfer.

For a Mars application, the transferable element is a record that links a remotely recognized target with the evidence required from a rover or surface observer. For Titan, the same reasoning applies to selecting and interpreting measurements across rotorcraft-accessible sites. Differences in illumination, atmosphere, surface materials, sensor response, and operational constraints must be modeled and tested separately. No mission simulation, communications-delay experiment, autonomous selection trial, or planetary performance estimate was conducted in this case study.

The companion website extends the poster by exposing source images, their dates, and candidate image-space annotations. It is an exploratory communication tool, not a shared scientific database or a validated geographic information system. It does not currently collect all visitors' points into a common repository. A future evaluation could compare target choices made with original photographs alone and with documented reconstructions, using predefined tasks and independent reference observations. Such an evaluation would test a benefit that the present descriptive case cannot quantify.

Limitations

The review is limited by purposive image selection, unverified camera timing, incomplete reconstruction provenance, unavailable processed footage, absent independent geometric control, and missing ground-site coordinates. The number of files should not be interpreted as an effective sample size for any environmental hypothesis. Only a small number of views illustrate the paper; no formal inter-observer agreement or feature-detection accuracy was measured.

The ground video's uncorrected projection limits geometric interpretation, while the year difference prevents assuming contemporaneous conditions even if a future spatial match is established. The supplied regional route screenshot and historical waypoints have not been registered to the imagery for this paper. Neither historical context nor proximity alone is sufficient to label the illustrated outcrop as part of the drone survey footprint.

The manuscript therefore supports a methods and provenance case study. It does not substantiate active hydrothermal activity, biological signatures, or a quantitative advantage of aerial reconnaissance. Those questions require their own evidence and should not be inferred from the images or from the planetary framing.

Conclusions

The FMARS imagery collection supports a documented inventory and descriptive examples of terrain, infrastructure, and snow or channel context. Trevor Jahn's July 2025 footage contributes a separate ground perspective. Their integration remains a testable objective because geographic correspondence and reconstruction accuracy have not been established.

The worked example preserves the source image, selected pixel, descriptive observation, and unresolved ground question in one record. The workflow requires geographic and temporal validation before incorporating measurements. For planetary reconnaissance, this offers a practical way to retain the evidence behind a request for surface investigation. Its effectiveness and geometric accuracy require independent evaluation.

Data and code availability

A selected image explorer and poster review are available at https://arctic.space4all.space. The site is public and labeled pre-release. It is a changing project companion, not a versioned archival

dataset with a DOI. The complete original image collection, native ground video, field records, and independently validated geospatial products have not been deposited with this manuscript.

The worked-example record is available at https://arctic.space4all.space/downloads/DEMO-0040-CENTER.json and is reproduced in Table 2. The local manuscript preparation package also retains the image inventory, video-frame manifest, figure source identifiers, and Python preparation routines. Public archival deposition of the complete supporting collection remains future work; the reproduction permission for the illustrated source imagery does not grant unrestricted redistribution of all original files.

Acknowledgments and contributions

Rhett Woods acquired the UAS imagery and supplied acquisition information. Tash Coelho contributed reconstruction and regional mapping work. Trevor Jahn filmed the July 2025 ground video. Adrian, whose surname remains to be confirmed, geolocated historical points used in the broader project. The author confirms permission to reproduce the contributed photographs and video frame. The acknowledgment does not imply that these contributors have reviewed or endorsed this manuscript.

Declarations

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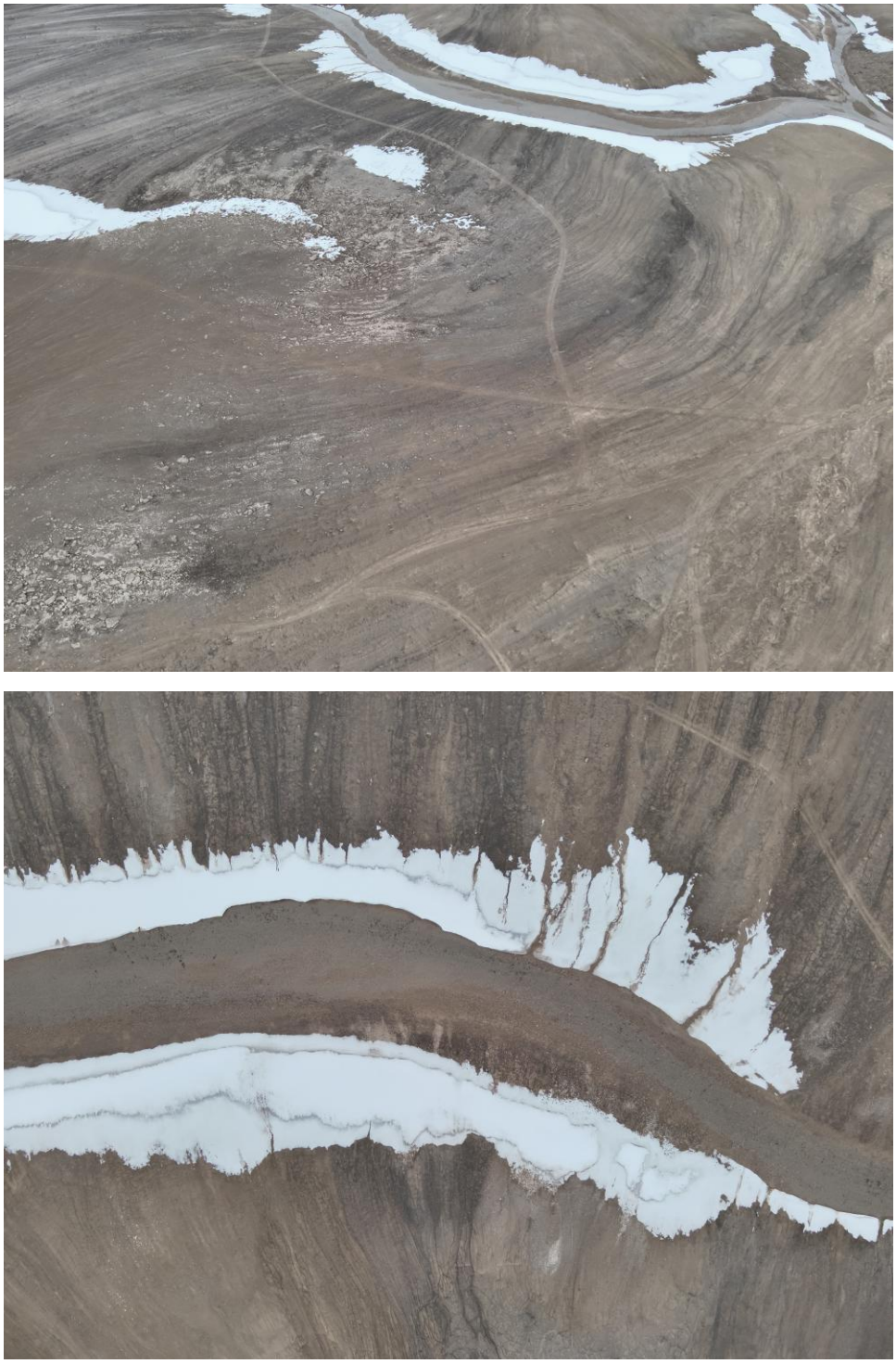
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Figure 1 FMARS field setting



Original UAS photograph of the FMARS habitat and surrounding ground. Source DJI_20260710112129_0056_V.JPG, 10 July 2026 at 11:21:29 by camera metadata; timezone unconfirmed. Imagery by Rhett Woods. Full image framing is preserved. This is a context photograph, not a georeferenced map, and no scale or north arrow is assigned. Reproduced with permission. Image material is excluded from the manuscript CC BY 4.0 license.

Figure 2 Aerial terrain and channel context



Upper: DJI_20260710113605_0233_V.JPG. Lower: DJI_20260710112011_0040_V.JPG. Both photographs carry 10 July 2026 timestamps and show terrain, snow patches or margins, and linear surface features. Imagery by Rhett Woods. Full image framing is preserved. Panels are separate source views, not a registered mosaic or a before-and-after comparison. No flow direction or erosion rate is inferred. Reproduced with permission. Image material is excluded from the manuscript CC BY 4.0 license.

Figure 3 Ground video review frame



Ground video filmed by Trevor Jahn in July 2025, as confirmed by the author. Source VID_20221212_141837_10_028_gossan_neearby.insv, decoded frame 818 at approximately 34.08 s. The filename date is incorrect. The author identifies the location as near a gossan; site coordinates and correspondence with the aerial coverage remain unconfirmed. The original decoded lens projection is retained, with strong distortion visible. This frame supplies qualitative ground context and no geometric or mineralogical measurement. Reproduced with permission. Image material is excluded from the manuscript CC BY 4.0 license.