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Small Business Innovation Research(SBIR) Program - Proposal Cover Sheet

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SBIR Phase I Proposal

Proposal Number:	**F244-0001-0028**
Proposal Title:	**SkyLine: Structured Knowledge Graphs with Integrity & Lineage**

Agency Information

Agency Name:	**USAF**
Command:	**AFMC**
Topic Number:	**AF244-0001**

Firm Information

Firm Name:	**Smart Information Flow Technologies, d/b/a SIFT**
Address:	**319 1st Ave North Suite 400, Minneapolis, MN 55401-1689**
Website:	**http://www.sift.net**
UEI:	**HT19FEFNVXC5**
DUNS:	**103477993**
CAGE:	**1NHZ1**
SBA SBC Identification Number:	**000000276**

Firm Certificate

OFFEROR CERTIFIES THAT:

1. It has no more than 500 employees, including the employees of its affiliates.	**YES**
2. Number of employees including all affiliates (average for preceding 12 months)	**35**
3. The business concern meets the ownership and control requirements set forth in 13 C.F.R. Section 121.702.	**YES**
4. Verify that your firm has registered in the SBAS Company Registry at www.sbir.gov by providing the SBC Control ID# and uploading the registration confirmation PDF:	**SBC_000000276**

Supporting Documentation:

- SBC_000000276.pdf

5. It has more than 50% owned by a single Venture Capital Owned Company (VCOC), hedge fund, or private equity firm	**NO**
6. It has more than 50% owned by multiple business concerns that are VOCs, hedge funds, or private equity firms?	**NO**
7. The birth certificates, naturalization papers, or passports show that any individuals it relies upon to meet the eligibility requirements are U.S. citizens or permanent resident aliens in the United States.	**YES**
8. Is 50% or more of your firm owned or managed by a corporate entity?	**NO**
9. Is your firm affiliated as set forth in 13 CFR Section 121.103?	**NO**
10. It has met the performance benchmarks as listed by the SBA on their website as eligible to participate	**YES**
11. Firms PI, CO, or owner, a faculty member or student of an institution of higher education	**NO**
12. The offeror qualifies as a: [ ] Socially and economically disadvantaged SBC [ ] Women-owned SBC [ ] HUBZone-owned SBC [ ] Veteran-owned SBC [ ] Service Disabled Veteran-owned SBC [**X**] None Listed	
13. Race of the offeror: [ ] American Indian or Alaska Native [ ] Native Hawaiian or Other Pacific Islander [ ] Asian [**X**] White [ ] Black or African American [ ] Do not wish to Provide	
14. Ethnicity of the offeror:	**NON-HISPANIC**
15. It is a corporation that has some unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have not been exhausted or have not lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability:	**FALSE**
16. Firm been convicted of a fraud-related crime involving SBIR and/or STTR funds or found civilly liable for a fraud-related violation involving federal funds:	**NO**
17. Firms Principal Investigator (PI) or Corporate Official (CO), or owner been convicted of a fraud-related crime involving SBIR and/or STTR funds or found civilly liable for a fraud-related violation involving federal funds:	**NO**

Signature:

Printed Name	Signature	Title	Business Name	Date
Harry Funk	/Harry B. Funk/	Vice President, R&D	Smart Information Flow Technologies, d/b/a SIFT	12/11/2019

Audit Information

Summary:

Has your Firm ever had a DCAA review?	**YES**
	Last Audit Date: **02/20/2020**
Was your accounting system approved by the auditing agency?	**YES**
	Last Update Date: **03/09/2023**
Was a rate agreement negotiated with the auditing agency?	**YES**
	Last Update Date: **03/14/2014**
Was an overhead and/or cost audit performed?	**YES**
	Date of Overhead Audit: **03/07/2014**
	Date of Cost Audit: **03/07/2014**
Are the rates from the audit agreement used for this firms proposal?	**YES**

Firm Information:

Agency Firm:	**DCAA, Minneapolis Branch Office**
Address:	**316 Robert St N, STE 615 St. Paul , Minnesota 55101**
Point of Contact (POC) Name:	**Melissa Scherf**
POC Phone:	**(763) 744-5520**
POC Email:	**Melissa.Scherf@dcaa.mil**

Upload a copy of the audit information:

- LETTER 2023MAR Final Determination Accounting System Approved.pdf

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VOL I - Proposal Summary

Summary:

Proposed Base Duration (in months):	**6**

Technical Abstract:

SIFT proposes to build SkyLine (Structured Knowledge Graphs with Integrity & Lineage) to innovate how human-machine teams collaboratively visualize, revise, and extend all-source knowledge graphs with high integrity. Knowledge graphs support

intuitive human visualization and concept-mapping, and they often have formal semantics that supports machine reasoning, so SkyLine will leverage knowledge graphs to (1) help humans express objectives, tasks, and queries to their machine teammates, and (2) help machines express results, conflicts, assumptions, and other tradecraft considerations to their human operators. This incurs some key research challenges, which SIFT proposes to address by leveraging recent R&D advances in AI/ML and human factors. One challenge is integrating data from authoritative, high confidence sources alongside emerging data from unfamiliar sources, without losing track of confidence and data integrity. To this end, SIFT proposes to use our TRL-7 provenance-based approach that tracks and visualizes the object-based production, sourcing, reliability, conflict, and corroboration of mission data. Another challenge is managing machine collaborators' contributions to the knowledge graph and ensuring that human operators are not overloaded, misled, or distracted by machine inferences. SkyLine will prioritize machine contributions by mission relevance (using spreading activation over the knowledge graph), inferential confidence, and source reliability, and will allow sorting by other desiderata, to help surface the most relevant, highest-utility machine contributions. SIFT brings technologies for multimodal visualization and provenance analysis that has been used in U.S. IC and DoD mission environments to mitigate risk and address these challenges early in Phase I. SIFT is well-positioned with transition customers in the DoD and IC to build SkyLine and deliver it to analysts who need it.

Anticipated Benefits/Potential Commercial Applications of the Research or Development:

SkyLine will most directly benefit analysts who access information from diverse sources and integrate data into a central knowledge graph or other mission representation. This task of mission-based information integration is often conducted under time pressures and under requirements for analytic standards (IC Directive 203) and sourcing (IC Directive 206), and while analysts may have access to intelligent software tools, these tools may be burdensome to run and understand. SkyLine will facilitate this work by letting analysts use the knowledge graph to express objectives and tasks for machine teammates to complete, and then providing the machines an API for tracking their provenance (i.e., operations, inputs, and outputs) to ensure that SkyLine tracks the lineage of machine contributions. SkyLine's provenance will jointly (1) improve analysts' sensemaking about machine contributions to the knowledge graph, and (2) facilitate the analysts' compliance with IC Directives, since the provenance connects each knowledge graph node and link back to the foundational sources. In addition to helping military analysts, SkyLine has commercially-viable capabilities of reducing the time and complexity of collecting information, characterizing patterns, and accruing evidence and counter-evidence in a mission-oriented setting. SkyLine has the potential to identify novel human-machine interaction patterns for all-source or OSINT analysis, in addition to providing novel graph schemas for human-machine workflows.

Attention:

Addition:

Enter the page numbers separated by a space of the pages in the proposal that are considered proprietary:

1 2 3 4 5 6 7 8 9 10 11 12 13 17 18 19 20 21 22 23 24 25 26

List a maximum of 8 Key Words or phrases, separated by commas, that describe the Project:

knowledge graphs, intelligence analysis, human-machine teaming, HMI, AI, provenance, tradecraft, information extraction

VOL I - Proposal Certification

Summary:

1. At a minimum, two thirds of the work in Phase I will be carried out by your small business as defined by 13 C.F.R Section 701-705. The numbers for this certification are derived from the budget template. To update these numbers, review and revise your budget data. If the minimum percentage of work numbers are not met, then a letter of explanation or written approval from the funding officer is required. Please note that some components will not accept any deviation from the Percentage of Work (POW) minimum requirements. Please check your component instructions regarding the POW requirements.	**YES**
Firm POW	**100%**
Subcontractor POW	**0%**
2. Is primary employment of the principal investigator with your firm as defined by 13 C.F.R Section 701-705?	**YES**
3. During the performance of the contract, the research/research and development will be performed in the United States.	**YES**
4. During the performance of the contract, the research/research and development will be performed at the offerors facilities by the offerors employees except as otherwise indicated in the technical proposal.	**YES**
5. Do you plan to use Federal facilities, laboratories, or equipment?	**NO**
6. The offeror understands and shall comply with export control regulations.	**YES**
7. There will be ITAR/EAR data in this work and/or deliverables.	**YES**
8. Has a proposal for essentially equivalent work been submitted to other US government agencies or DoD components?	**NO**
9. Has a contract been awarded for any of the proposals listed above?	**NO**
10. Firm will notify the Federal agency immediately if all or a portion of the work authorized and funded under this proposal is subsequently funded by another Federal agency.	**YES**
11. Are you submitting assertions in accordance with DFARS 252.227-7017 Identification and assertions use, release, or disclosure restriction?	**YES**
12. Are you proposing research that utilizes human/animal subjects or a recombinant DNA as described in DoDI 3216.01, 32 C.F.R. Section 219, and National Institutes of Health Guidelines for Research Involving Recombinant DNA of the solicitation:	**NO**

13. In accordance with Federal Acquisition Regulation 4.2105, at the time of proposal submission, the required certification template, "Contractor Certification Regarding Provision of Prohibited Video Surveillance and Telecommunications Services and Equipment" will be completed, signed by an authorized company official, and included in Volume V: Supporting Documents of this proposal. NOTE: Failure to complete and submit the required certifications as a part of the proposal submission process may be cause for rejection of the proposal submission without evaluation.	**YES**
14. Are teaming partners or subcontractors proposed?	**NO**
15. Are you proposing to use foreign nationals as defined in 22 CFR 120.16 for work under the proposed effort?	**NO**
16. What percentage of the principal investigators total time will be on the project?	**20%**
17. Is the principal investigator socially/economically disadvantaged?	**NO**
18. Does your firm allow for the release of its contact information to Economic Development Organizations?	**YES**

VOL I - Contact Information

Principal Investigator

Name:	**Dr. Scott Friedman**
Phone:	**(314) 640-9077**
Email:	**sfriedman@sift.net**
Address:	**319 1st Ave North Suite 400, Minneapolis, MN 55401 - 1111**

Corporate Official

Name:	**Kara Stegeman**
Phone:	**(651) 399-1303**
Email:	**kstegeman@sift.net**
Address:	**319 1st Ave North Suite 400, Minneapolis, MN 55401 - 1111**

Authorized Contract Negotiator

Name:	**Kara Stegeman**
Phone:	**(651) 399-1303**
Email:	**kstegeman@sift.net**
Address:	**319 1st Ave North Suite 400, Minneapolis, MN 55401 - 1111**

SKYLINE: Structured Knowledge Graphs with Integrity & Lineage

1 Identification and Significance of the Opportunity

Analysts and operators in the U.S. military and Intelligence Community (IC) must collaboratively attend to complex missions over time, information sources, collection disciplines, and modalities. As Artificial Intelligence (AI) and machine learning (ML) gains acceptance, analysts also need innovative ways to communicate with these machines with low ambiguity, high integrity, and high expressiveness, all while avoiding information overload and complying with directives for standards [1] and sourcing [2].

Knowledge graphs (KGs) have been used for decades to visualize data—notably including cognitive maps [3] and analysis-oriented link diagrams [4, 5, 6, 7]—and they likewise support semantic representations for machine-based reasoning [8], planning [9], and matching [10]. KGs can support human-machine information interchange, provided (1) humans can use KGs to express and visualize complex mission concepts (§2.2), (2) machines can contribute in like fashion with accurate confidence (§2.3), (3) machine contributions do not overload analysts (§2.4), and (4) the KG elements are linked to alternative hypotheses and traceable back to the foundational sources to support high rigor [11] and sensemaking [12] (§2.5).

SIFT proposes to develop SKYLINE to facilitate high-integrity, low-ambiguity, human-machine KG-based interaction. As shown in Figure 1, teams of humans will interact via SKYLINE to articulate mission context and objectives in a diagrammatic UI, with semantic underpinnings for interoperability with machine teammates. SKYLINE's structural knowledge representation will include mission data and domain-general schemas for spatiotemporal qualifiers, provenance [13], and quality control (QC) for tradecraft (e.g., [14]) (§2.5). SKYLINE is informed by SIFT's provenance-based intelligence analysis approach [14, 8] that was designed under AFRL SBIRs (§4.2), recognized as an Air Force SBIR Success Story, and transitioned to TS/SCI environments as a data model of DIA's MARS program (§4.3) to replace MIDB. SIFT will leverage this recent work—including a graph store, data models, and UI components—to mitigate risk in Phase I.

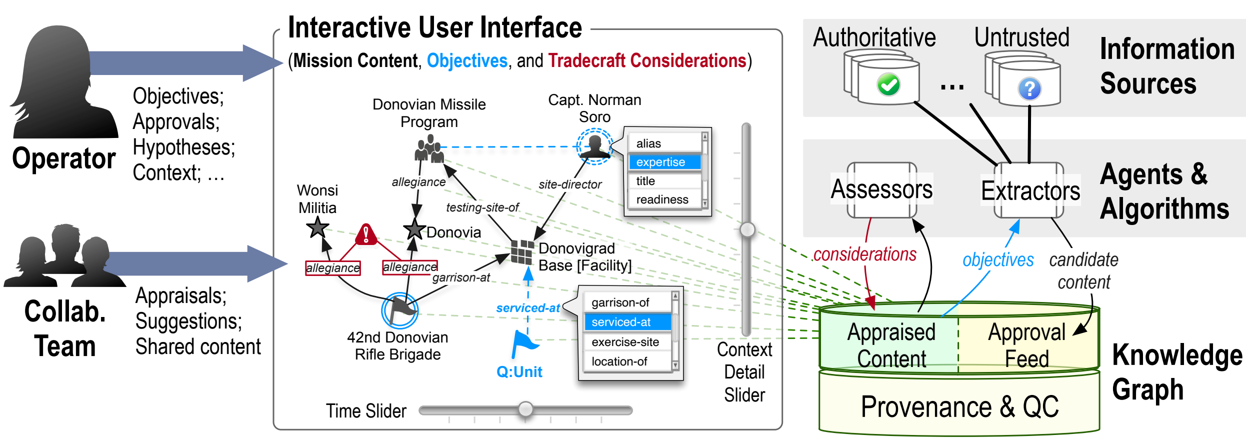

Figure 1: SKYLINE flow: the operator and her teammates interact with a graphical UI of the KG, specifying context, hypotheses, and objectives; machine agents attend to objectives by processing diverse information sources and adding content with full provenance, for prioritized human approval.

The SKYLINE team brings relevant expertise and usable software in support of SKYLINE's technical objectives. SIFT PI Dr. Scott Friedman (§7.1) recently led the Project7 and GEMINI AFRL SBIR projects for high-integrity human-machine intelligence analysis (§4.2) with spatiotemporal and knowledge-graph interfaces [14, 8, 15, 7] advised in part by Air Combat Control (ACC) and the National Air and Space Intelligence Center (NASIC). He led two technology acquisition projects to transition this knowledge graph technology to the Defense Intelligence Agency's MARS program (§4.3), for all-source analysis of authoritative emerging TS/SCI data on JWICS/Dev. SIFT Co-PI Dr. Drisana Iverson (§7.2) is an AI/LLM specialist, having implemented graph-based interaction with LLMs for DARPA HABITUS and DARPA Civil Sanctuary. SIFT researcher Dr. Matthew McLure (§7.3) is an expert in graph- and pattern-matching (§2.3.1) [10] including in geospatial domains, and leads a DARPA Collaborative Knowledge Curation program (§4.5) for extracting, displaying, and revising knowledge graphs of mission data.

SIFT brings expertise in knowledge graph analysis, human-machine interaction, analytic integrity, and knowledge-rich missions that combine authoritative and emerging data sources. We expect to leverage technologies in these areas to make early strides and meaningful prototypes of our approach in Phase I. The transition paths that SIFT has already established (§6.2, §4.3) will help ensure that SKYLINE technology reaches the hands of the analysts that need it.

2 Phase I Technical Objectives

Over the course of all SBIR phases SKYLINE will **enable high-integrity, low-ambiguity knowledge graph interaction with full provenance** in human-machine team intelligence analysis. Meeting that objective faces the following high-level technical challenges, expressed as research questions:

► **(§2.2) How will SKYLINE allow expressive human-machine analysis using knowledge graphs?**

Informed by previous work, SKYLINE will display the domain-level content of knowledge graphs for human perusal and collaboration; however, SKYLINE will *also* allow analysts to diagrammatically annotate (1) *importance* over existing entities and relations, (2) *collection tasks* on existing entities and relations, and (3) *patterns of interest* as key attributes or relations that are not yet known. SKYLINE will also display tradecraft factors—such as conflicts, gaps, risks, and alternatives—to improve the rigor of the analysis. We describe this further in Section 2.2.

► **(§2.3) How will SKYLINE facilitate machine contributions to the mission KG?**

When backed by formal semantics, KGs can support machine reasoning, e.g., to support consistency-checking and information extraction from documents and semantic web resources. Advised by SIFT's work on all-source analytics for DIA's MARS program (§4.3), we propose for SKYLINE semantic elements to have falsifiable identifiers that point to remote sources, e.g., so a single military unit in the KG might refer to a single record in an authoritative data source like MIDB, and it may also refer to one or more alternative objects in imagery. Identifiers, coreference-tracking, and strong semantics will facilitate machine coordination in SKYLINE, which we describe further in Section 2.3.

► **(§2.4) How can analysts approve machine inferences without incurring an information overload?**

As data and analysis software increase in complexity, many inferences and knowledge graph extensions may be possible, and these inferences risk overloading—or even distracting or misleading—the analyst. SKYLINE will include a priority queue that will compute a unified ranking by scoring each inference over the following dimensions: (1) scoring by mission-relevance using users' importance annotations (see Section 2.2); (2) scoring by confidence/likelihood using the output of ML models; and (3) scoring by analytic impact based on provenance traversal (see Section 2.5). We describe this further in Section 2.4.

► **(§2.5) How can humans and machines to contribute to a KG with transparency & integrity?**

In addition to accurate judgments, the analysis process should help analysts derive meaning and understand the factors that impact analytic confidence. This is advised, in part, by integrity-focused IC directives [1, 2] and metrics of analytic rigor [11]. We discuss SIFT's provenance-based solution to supporting sensemaking, integrity, and rigor in Section 2.5.

► **(§2.6) How will SIFT measure success in human-machine KG interaction?**

In our R&D we must assess the soundness, relevance, expressiveness, interoperability, and efficiency of our approach to assess progress and design trade-offs. We describe relevant industry standard metrics and novel metrics for this R&D in Section 2.6.

2.1 Relevant Work Informing the SKYLINE Approach

SKYLINE is informed by several previous works in viewing, updating, and working with knowledge graphs (KGs). Alignment of KGs is essential, since multiple data sources may refer to entities differently, but these sources must be reconciled for a user to incorporate the sources. Yan et al. [16] propose a KG alignment algorithm that outperforms several algorithms in the setting where the graphs are static, but, more importantly, leads to two fast algorithms to align dynamic (changing) knowledge graphs, which are relevant to the SKYLINE use case, where both the environment and the users' needs may be dynamic. Additional approaches for dynamic KG alignment and completion include the user of LLMs [17]. Additionally, previous works have tested the correctness of automated KG updates through algorithmic graph transformations when applied to the public health domain [18].

Additionally, viewing KGs at the appropriate level of granularity is crucial in order to avoid, on the one hand, overwhelming a user with too much detail, and on the other hand, providing such a high-level view as to lack information. Nechasky and Martin's Interactive KG Browser [19] allows users to filter the connectivity of the graphs, and allows experts to hide different details that may be less relevant to users. Vargas et al.'s RDF Explorer [20] addresses the issue that, in order to query KGs, we need to know how to formulate queries in the relevant query language, and how entities of interest are described within the graph, both of which may pose problems depending on a user's expertise level. They explore various methods that allow lay users to leverage information within KGs, such as keyword search, faceted browsing, query building, graph summarization, and visualization techniques. Their tool emphasizes the importance of avoiding interactions with the graph that yield empty results, so the RDF Explorer allows users to visually build relevant queries. Further, Ehrhart's KG Explorer [21] adjusts based on both the domain that is covered by the KG and the "persona", or user profile, of a user (e.g., novice, stakeholder, expert) while explaining the key needs of each type of user.

SKYLINE is also informed by various approaches to gauge attention on different KG nodes. Spreading activation theory [22] provides a framework for semantic search between various concepts in a KG. This can be applied to an analyst's KG in order to view parts of the graph that may be important to them, given proximal nodes they've paid attention to before. Spreading activation models can also be helpful for information retrieval both in terms of associative feedback and relevance feedback [23], and can be useful in order to help with querying and keyword search when a user wants to actively search a KG [24].

2.2 Expressive, Low-Ambiguity Communication in Knowledge Graphs

Previous work on KG user interfaces (UIs) facilitate human understanding of causal relationships [3] or semantic relationships [20], including relational information extracted by machines [6, 7]. Previous work has also explored dynamic KG UIs that modulate the level of detail [19], e.g., for dynamic or rapid display

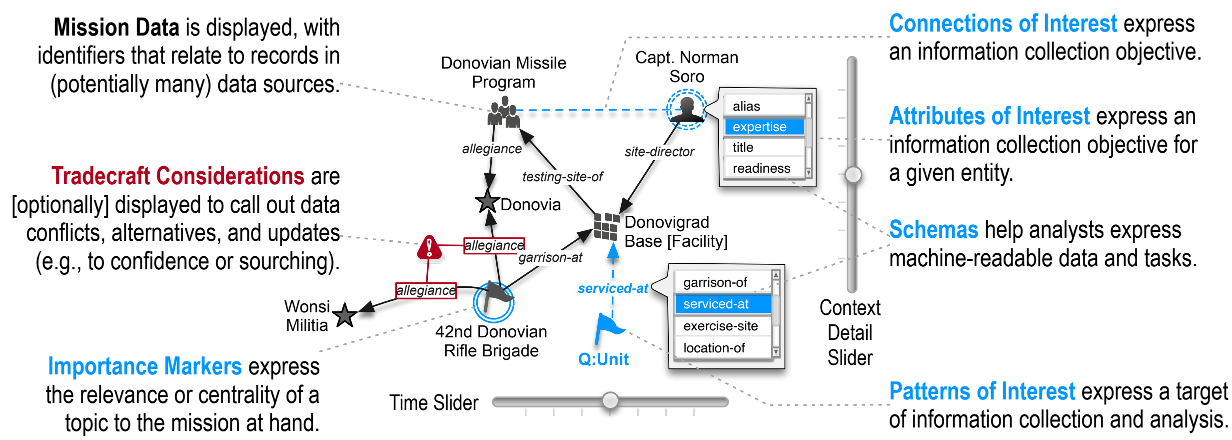

Figure 2: SKYLINE's expressive KG interface will allow human users to (1) *inspect* mission data and tradecraft considerations in an intuitive fashion, and (2) *express* importance and analytic tasks to machine teammates in the same interface.

of relevant information [16]. SKYLINE is informed by these recent developments, and also brings novel expressivity and dynamics to KGs.

As illustrated in Figure 2, we propose to enhance the KG display to enrich the traditional plot of *mission data* with other annotations that use the mission data as a scaffold. Theses include the following:

- **Tradecraft Considerations** are alerts or updates that impact the integrity or the direction of subsequent analysis, such as the red conflict between the two mutually-inconsistent *allegiance* edges in Figure 2. Tradecraft considerations may be recognized by consistency-checking software agents, or they could comprise alerts when new information is available, when a supporting source has been refuted (by traversing provenance, as we show in Section 2.5), or when a colleague has rated or appraised a hypothesis (see Figure 8).
- **Importance Markers** are annotations that an analyst adds atop the mission data to indicate the centrality or priority of a topic or relationship for the mission-at-hand. These will be used to prioritize SKYLINE's feed of content for analyst approval (§2.4), and they could also be used to guide the attention of proactive machine information-collectors that integrate with SKYLINE.
- **Connections of Interest** are annotated links between entities in the KG that are of interest for additional information collection. For instance, in Figure 2, the analyst expressed an interest in connecting *"Capt. Normal Soro"* to the *"Donovian Missile Program."* We envision that these could be specified further, e.g., so the analyst can express collection disciplines of interest (e.g., COMINT, IMINT) or specific data sources of interest.
- **Attributes of Interest** are field-level interests for information collection, e.g., finding the *"expertise"* of the individual *"Capt. Norman Soro."* Attributes could comprise any data field that is not relational in nature.
- **Patterns of Interest** express an interest in an unknown or hypothetical entity, e.g., Figure 2 expresses an interest in finding all units that are serviced at the *"Donovigrad Base"* facility. As with the above annotations, these are useful for guiding machine teammates and prioritizing mission-relevance.
- Two of the annotations use **schemas** (i.e., listings of attributes or relations) for specifying tasks. Formal schemas, such as those employed by MIDB, Wikidata, DBPedia, DICO, etc., improve the uniformity of data and ensure that tasks and objectives conform to a machine-readable, doctrinal semantics. When possible, SKYLINE will encourage users to use formal schemas rather than arbitrary textual relations, though the latter will also be available.

The above expression strategies will improve SkyLine's responsiveness to use objectives as well as its ability to assess the relevance of new content to the mission-at-hand (§2.4). Moreover, we hypothesize that expressing the intelligence collection goals and tasks as shown in Figure 2 may also improve human-human collaboration and analysts' situation awareness, which would comprise dependent variables for human subject research in future phases.

In addition to the various annotations shown in Figure 2, we envision dynamic *"sliders"* for modulation:

1. The horizontal **Time Slider** in Figure 2 will be a point or window of enabled time, fading out the content that has no evidence within the specified temporal window. For instance, if the *allegiance* of the Brigade in Figure 2 was once *"Donovia"* and then it changed subsequently to *"Wonsi Militia"* at a later time, this may not be a true data conflict, since they are temporally disjoint. The temporal slider will help bring these insights to light.
2. The vertical **Context Detail Slider** in Figure 2 will marshal additional connected nodes and relations into the visible knowledge graph, prioritizing entities and connections adjacent to nodes with importance-markers. The user will be able to "pin" these retrieved elements to their mission-level KG. Likewise, when they dial down the detail, the un-pinned contextual entities will vanish again.

As we describe later in Section 2.5's discussion of provenance, we propose tracking confidence, sensitivity, and foundational sources, so SkyLine could also exploit these dimensions to display confidence sliders (e.g., only showing elements with high analytic confidence) and so-forth.

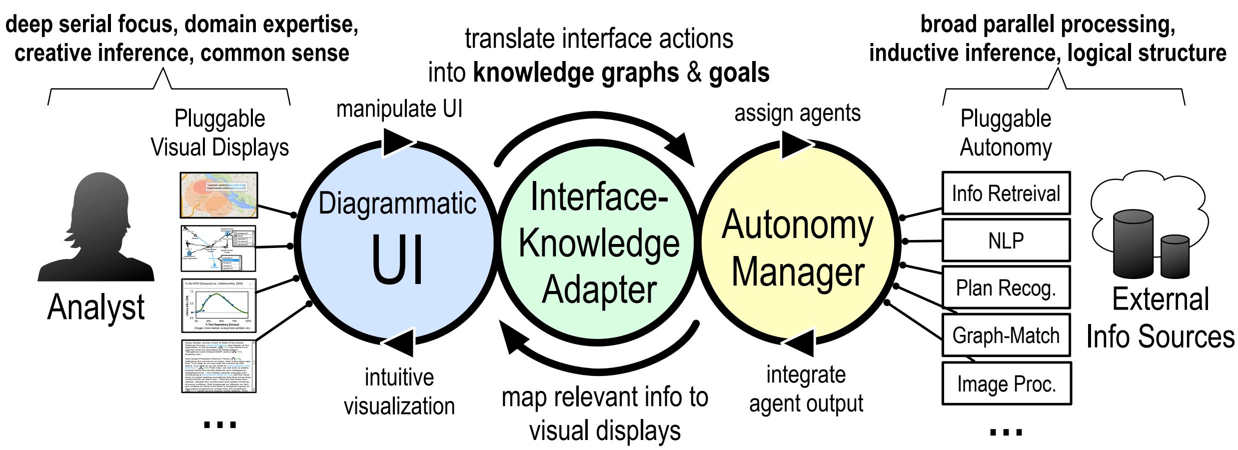

Figure 3: Conceptual view of shared human-machine perception, developed under "Project7" AFRL 711 HPW/RHXM SBIRs (§4.2), persistently mapping between (a) analysts' diverse displays and (b) machine knowledge graphs, marshaling information between teammates to communicate inferences and attention.

2.3 Facilitating Machine Reasoning with KGs

Semantically-grounded KGs have the advantage of supporting structured (i.e., graph-based, database-based, or symbolic) machine reasoning, and also depicting information intuitively for human users. We refer to this as *shared human-machine perception* and we have developed this concept under AFRL SBIRs (§4.2), as shown in Figure 3.

This human-machine team framework allows autonomous machines to collaborate in concert with humans, in the same workspace, with low ambiguity. As exemplified in Figure 3 (right side), we envision diverse autonomy integrating with the SkyLine knowledge graph software, tasked by the user as described in Section 2.2. Plausible autonomous agents include:

- **Information Retrievers** that query structured data sources for items of interest using names, identifiers, and other properties, for ingestion into the SkyLine graph store.
- **NLP / Information Extractors** process retrieved unstructured data and extract relations and attributes of interest to the mission.
- **Plan Recognizers** process raw observations to infer higher-level events, relations, and red-force tactics, techniques, and procedures (TTP) to advance the analysis.
- **Graph-Matchers** use the central mission knowledge graph as a *probe* and then match it against a library of previous observations to retrieve useful precedents, e.g., for context and predictive analysis (see Section 2.3.1 for more on the Align algorithm).
- **Image Processors** and other media analytics extract and characterize objects and activities from feeds to advance the analysis.

The user's task-based and importance-based annotations in the KG (§2.2) will help trigger and guide these autonomous agents, and SkyLine will also provide an API for these agents to store their inferences with full provenance (§2.5).

Importantly, these diverse software agents may generate a massive volume of results with varying accuracy and source-reliability. Prioritizing these results for human approval and sensemaking is the responsibility of SkyLine's priority feed (described in Section 2.4).

In future SkyLine phases, we envision using NLP that SIFT developed under DARPA programs (§4.4, §4.1, §4.5), and information extraction agents (e.g., from Wikidata and websites) that SIFT developed under SBIRs, to implement practical machine tasking via SkyLine's KG. Depending on the Phase I research interests of AFRL program management, SIFT could potentially demonstrate a full-loop human-machine KG interaction where (1) the human expresses an objective (§2.2), (2) a software agent executes a relevant task for the objective and stores its results with provenance (§2.5), (3) SkyLine ranks the results for relevance (§2.4), and (4) the user approves it to extend the KG.

SIFT will identify practical use-cases for incorporating semantic graph-matching in SkyLine Phase I. For instance, one important question analysts face when presented with new observations is *"is this normal?"* Software agents can help answer this question with graph-matching over new and historical KGs, e.g., using our Align algorithm.

2.3.1 Align: Comparative Analysis and Graph Abstraction

SkyLine key personnel Dr. Matthew McLure (§7.3) developed the Align (Analogical Learning by Integrating Generalization and Near-misses) system for inductively matching, comparing, and abstracting structure from knowledge graphs [10]. Analogical comparison (i.e., labeled graph-matching) underlies both of the core learning processes in Align: (1) Comparing positive examples to negative examples to find structurally similar pairs that reveal hypotheses about concept criteria—so called *near-miss hypotheses*—and (2) comparing positive examples to one another to cluster and merge them into structurally similar abstractions (or "prototypes") that can then be used to refine near-miss hypotheses. The result of Align is a small set of representative knowledge graphs for each concept in which the nodes of the graph have associated probabilities to tease apart characteristic structure from noise, and some nodes inferred as central to the concept. Align's structured, probabilistic concept prototypes are highly interpretable and modifiable by human operators, and they can be converted into rules, patterns, and templates.

We have also used Align for similarity-based retrieval: Given a graph (or subgraph) of interest, retrieve similar examples or prototypes from Align's graph library. Align can then draw inferences from the retrieved graph into the graph-of-interest by matching the graphs and then *projecting* unmatched-but-connected nodes and edges from the previous graph into the graph of interst.

Optimal graph matching is NP-complete, so Align is built on an approximate matching algorithm motivated by cognitive science [25] that uses a greedy heuristic to avoid large search spaces. ALIGN's approach is agnostic to the graph matching process used, provided that this process produces an injective mapping (one-to-one allowing leftovers) and a numeric similarity score that is sensitive to structure and semantics.

ALIGN has been used to learn spatial concepts from datasets that include sketched objects, geospatial concepts, and cause-and-effect concepts. In SKYLINE, we will to apply ALIGN to more diverse knowledge graphs and subgraphs that mix spatial representations, authoritative Order-of-Battle relationships, and simulated raw intelligence data.

2.4 Prioritized KG Approval Feeds to Conserve Attention

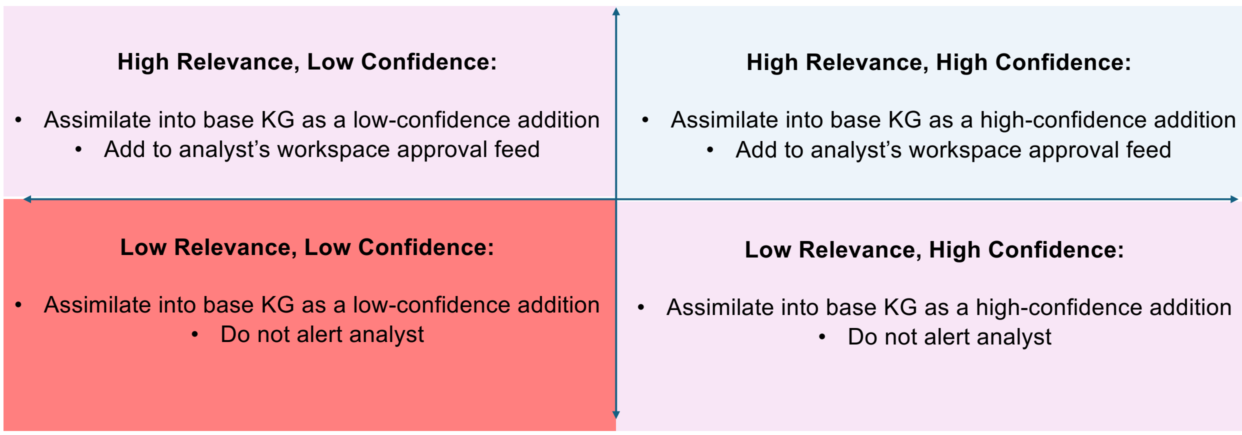

Figure 4: SKYLINE will allow for updates to the base (background) KG, while prioritizing the most relevant updates for the analyst's immediate review.

SKYLINE will strike a balance between informing analysts of important updates while avoiding information overload. To do so, we propose two distinct areas to update the KG:

- **Approval to the Base KG** will involve updating the base KG. As shown in Figure 4, the base KG may be updated to include sources with various levels of confidence. However, addition to the background KG does not mean that an analyst necessarily needs to review every update. Rather, their attention can be focused on updates that they have expressed interest in.
- **Approval to the Analyst's Workspace** will focus on bringing the highest-relevance updates to the analyst. As shown in Figure 4, low-relevance updates can be assimilated without alerting the analyst, but high-relevance updates can be displayed. Additionally, high-relevance and low-confidence updates may be flagged for review.

SKYLINE's priority queue for approval to the analyst's workspace will be based on the criteria of mission relevance and analytic impact. Mission relevance is determined by the analyst's importance annotations, as seen in Section 2.2. Nodes that are highlighted as important by the analyst will be assigned the highest priority, and additional nodes will be assigned a priority score based on proximity to the annotated nodes, using algorithms based on spreading activation [22, 23, 24]. Analytic impact will be based on traversal through the provenance, as discussed in Section 2.5. In doing so, priority will be given to nodes that have high confidence.

In the background, SKYLINE will add updates to the base KG, but can also provide snapshots of the base KG if an analyst prefers to freeze the state of the KG. This can provide the analyst an opportunity to create a finalized intelligence product based on the state of the world at a given time, without creating inconsistencies as new updates are brought in.

In SkyLine Phase I, we plan to explore tradeoffs between sharing updates of low quality and high relevance, and consider future HSR work in order to observe the level of feedback that is useful to an analyst without being misleading. The balance between confidence and relevance can be determined by observing the impact on metrics such as efficiency, F1, and other metrics discussed in Section 2.6.

2.5 Supporting meaning-making, integrity, and rigor

Machine analytics and raw intelligence data have become more complex in recent years, but the directives and standards for integrity [1, 2] and rigor [11] remain the same, and are arguably more important than ever. Also, integrity aside, SkyLine's machine inferences and additions to the shared knowledge graph are only useful if analysts can understand the machine-generated conclusions and meaningfully assess their confidence.

To this end, SkyLine will include interactive user interfaces (UIs) for visualizing, inspecting, validating, and comparing machine inferences. As shown in the SkyLine overview in Figure 1, SkyLine's users and agents will amend the KG, and these will then feed into these analyst-centric UIs. As a start, we will incorporate the interpretation UIs developed for the AFRL Project7 SBIRs (§4.2) and in transition to DIA's MARS program (§4.3). These interfaces have been informed by demonstrations and evaluations with tradecraft experts in DIA, ACC, and NASIC, and were developed by SIFT's Dr. Matthew McLure (§7.3) and Dr. Scott Friedman (§7.1). We have shown that these interfaces make inroads for analytic awareness and ICD compliance and improve explainability of complex analyses [14, 8].

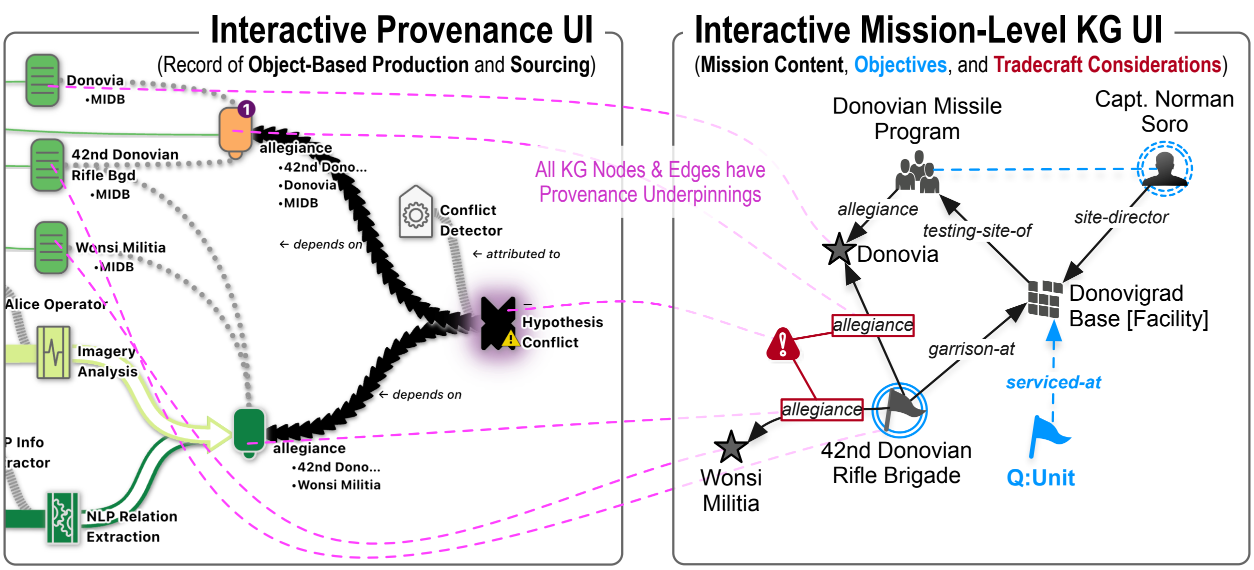

Figure 5: Informed by SIFT's provenance-analysis work under Project7, we propose for all of the mission-level data displayed in the user-facing UI (sketched at right) has full provenance underpinnings (screenshot at left). Although some inferences are represented as KG edges (e.g., the *allegiance* links), they are nodes with full lineage and sourcing in the underlying provenance graph (at left), which also has an interactive UI.

One of the primary meaning-making interfaces in Project7 (§4.2)—which was a prominent feature of our work on the MARS program (§4.3)—is the *provenance* interface. We define **provenance** as the record of production: how, when, why, and by-whom something was generated. To understand the relationship between *provenance data* (i.e., the record of production) and *mission data* (i.e., the data in maps and user-facing link diagrams), see Figure 5: all of the data in the user-facing link diagram (e.g., the nodes, links, objectives, and conflicts) have corresponding data in the provenance record, which can *also* be viewed as a knowledge graph (this is a screenshot from Project7, where we created a simple SKYLINE vignette).

The data in the provenance record (left side of Figure 5) includes data records about geopolitical entities (e.g., the fictional *"Donovia"* and *"Wonsi Militia"*), military units (e.g., *"42nd Donovian Rifle Bgd"*), and hypotheses about them (e.g., the brigade's *allegiance* is Donovia [top] or alternatively, Wonsi Militia [bottom]). There's also a *"Hypothesis Conflict"* between the two *allegiance* hypotheses, since (for instance) the unit cannot be allegiant to two disjoint organizations. The magenta links trace these provenance underpinnings to the right, to the mission-level KG UI, where some of these elements are rendered as edges (e.g., the *allegiance* labels), and others are rendered as nodes (e.g., the units and countries). Regardless their visualization in a link diagram, **every semantic element has a corresponding provenance record**.

Note that the provenance network in Figure 5 also contains information about production: *Imagery Analysis* and *NLP Relation Extraction* activities support the Wonsi Militia allegiance hypothesis, and a *Conflict Detector* agent has produced the hypothesis conflict. The mission-level KG *hides* these elements, since the mission-level KG should help the user attend to the *content* of the analysis and not the *process* of the analysis. That said, SKYLINE will include these provenance views for when the operator wishes to "drill down" and understand the rigor, sourcing, confidence, diversity, reliability, and alternatives. We describe how SKYLINE will help users exploit the provenance.

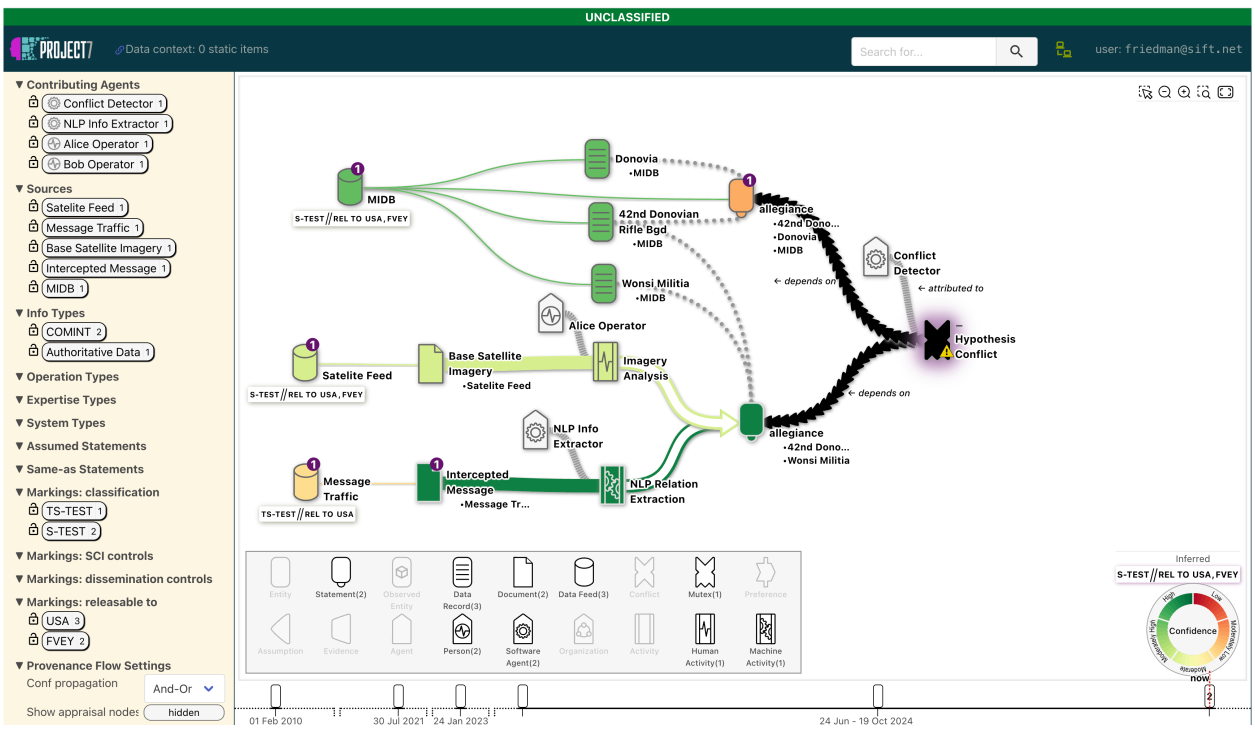

Figure 6: Screenshot of Project7 displaying a provenance graph of a fictional vignette representative of a SKYLINE analysis that integrates authoritative data sources (e.g., MIDB, upper left) with other emerging multi-INT data sources (e.g., a satellite feed and message intercepts, middle and lower left), supporting two conflicting hypotheses of a military unit's allegiance.

Retrieving and summarizing provenance. Suppose the operator wants to understand the conflict between the two *allegiance* hypotheses shown in Figure 5 to assess whether this brigade is allegiant to either of the alternatives. SKYLINE will use Project7's provenance traversal to start from the hypothesis-conflict-node, and trace back (i.e., leftward) through the provenance relations to the foundational sources and contributors. The result is shown in the provenance graph shown in Figure 6, a screenshot from Project7.

The left sidebar of Figure 6 shows the contributing agents (machines and humans), sources (per ICD 206 [2]), information types (i.e., INTs, supporting ICD 203 [1]), classifications (S and TS are labeled S-TEST and TS-TEST to avoid ambiguity), and releasibility markings (supporting ICD 403). The flow graph shows that many records are pulled from MIDB (though this is a fictional scenario), which has "S-TEST" classification. A Satellite Feed (also S-TEST) supports satellite imagery of a base, and a human user "Alice Operator" has conducted an "Imagery Analysis" activity that supports one of the *allegiance* hypotheses. That hypothesis is corroborated by an "NLP Relation Extraction" operation that was conducted by a machine, using an "Intercepted Message" from "Message Traffic" (TS-TEST). To the right, a "Conflict Detector" agent has generated a "Hypothesis Conflict."

The colors in Figure 6 indicate relative confidence, computed by graph propagation when a node (i.e., record or judgment) has not been directly appraised for confidence. Confidence propagates from sources (left) to conclusions (right) to facilitate confidence judgments [1] and information validation [11], also helping analyze competing hypotheses [11].

This approach is enabled by *provenance capture* (i.e., all user interfaces and machine agents must correctly record their provenance) and *provenance visualization* (i.e., we display the provenance to facilitate understanding). Intuitively, if we do not capture provenance correctly or completely, the visualization may be incorrect, incomplete, or misleading. We use the W3C's PROV ontology [26] and SIFT's DIVE ontology [14] to track provenance and tradecraft factors (e.g., INT types and other considerations). We propose to use this approach in SKYLINE.

Figure 6 depicts a moderately simple all-source analysis that uses authoritative data (MIDB) to support a hypothesis and emerging data to support an alternative. The timeline at the bottom of Figure 6 is also interactive, so we can assess the recency of the authoritative and emerging data. This UI is designed to facilitate a "conversation" with the data, so the user can ask *"what-if"* questions, as we describe next.

Sensitivity analysis. For various reasons, an analyst may want to—at least, temporarily—remove a source, contributor, assumption, or operation from their analysis and assess the impact. Per ICD 732, we may have acquired corrupt or misleading information, and we want to assess its impact; alternatively, we may want to see how confident we can be about a hypothesis if we remove a highly-classified source, for eventual release of the hypothesis to a non-U.S. collaborator.

Figure 7 illustrates the process of *refutation*: we have clicked the buttons for *"Satellite Feed"* and *"TS-TEST"* button in the left side-bar to disable these in our local view. Both elements are shown with red strike-through, and the flow-graph also depicts all TS-TEST elements (e.g., "Message Traffic") and the "Satellite Feed" as disabled, as well as all elements that *necessarily* rely on them. This ultimately disables the *allegiance* hypothesis downstream, leaving only one remaining *allegiance* hypothesis, from MIDB.

This allows the user to understand the information necessity and dependency structure of complex human-machine analyses that support their mission data. Importantly, Project7 only uses this refutation strategy on the provenance graph, but SKYLINE will *also* allow users to refute sources, INT-types, etc., and see the real-time impact in their mission-based knowledge graph.

The USPTO recently allowed SIFT patent 16/948,297 for these provenance analyses funded under the Project7 AFRL SBIR, and Dr. Scott Friedman and Dr. Matthew McLure have published papers about high-integrity, explainable AI using provenance [8, 9, 14].

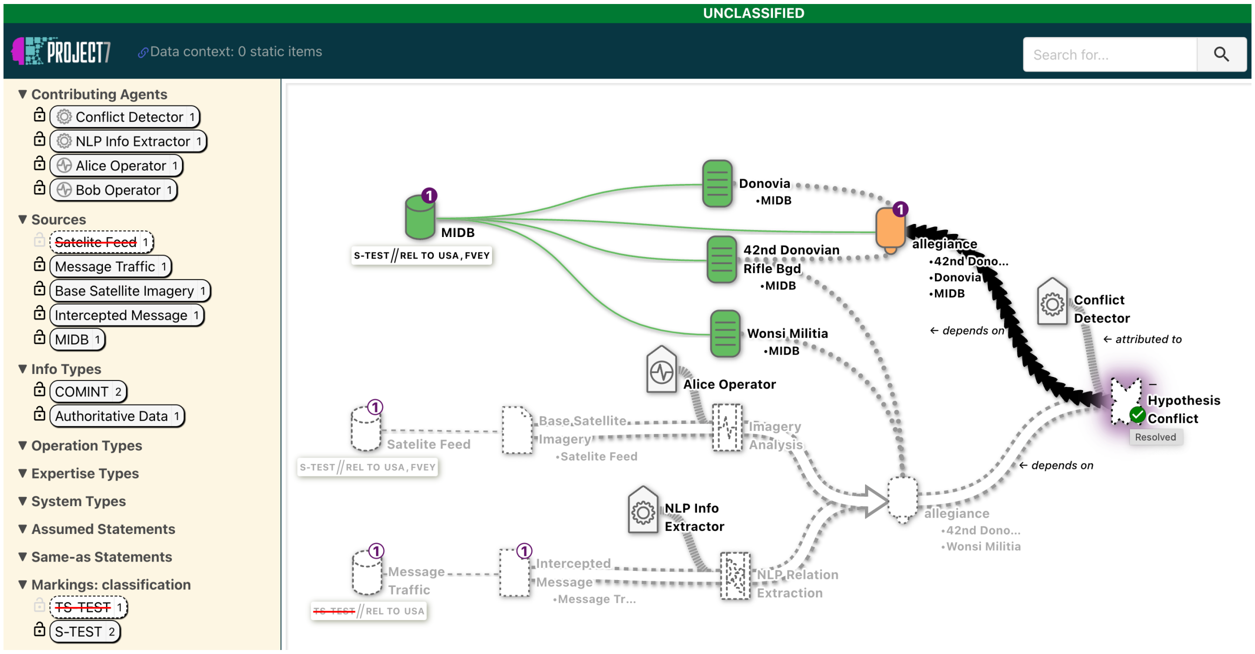

Figure 7: A "what-if" sensitivity analysis: When the user refutes TS-TEST classified data from the critical thinking panel, it displays with a red strikeout and removes all elements that necessarily rely on TS-TEST data from the analysis. Likewise, refuting the Satellite Feed removes that source and all dependent data. This removes all support for one of the allegiance hypotheses.

Confidence of mission data. Provenance and lineage alone cannot accurately dictate how confident we should be of our mission data; human experts and domain-specific reasoners are much better sources of confidence judgments. SIFT's provenance approach uses **Appraisals** to represent the confidence and quality judgments that any agent (human, machine, or organization) attributes to a data source or analytic judgment. One such appraisal is shown in Figure 8: a human analyst *"Bob Operator"* ascribes low confidence to the MIDB record about the brigade's allegiance, commenting that it may be outdated. Multiple users or machines can appraise a single element in the provenance, and appraisals are applied wherever the information is used, potentially across many scenarios. The confidence of each local element is propagated downstream (i.e., to the right) to estimate the confidence of un-appraised elements. This allows experts to weigh in on a single node or link, and their appraisal will have a potentially broad focus.

A Report Card for mission data. In addition to propagating *forward* (i.e., downstream, to the right) to spread confidence, the provenance analysis traverses *backward* (i.e., upstream, to the left) from a hypothesis or conclusion of interest to identify foundational sources, supporting observations, contributors, assumptions, and so-forth. In IC doctrine, these upstream factors are critical for tradecraft [1] sourcing [2], and they help populate an intelligence product, e.g., to articulate confidence.

We aggregate this information into a *report card*. Figure 9 depicts a report card for one of the *allegiance* hypotheses, including the estimated confidence and INT support (top) and many other considerations below, including *confidence sensitivities*, which lists the confidence that would be lost if various elements were unilaterally removed from the analysis. This shows us that—of the sources that support this hypothesis—much of the confidence is drawn from the Intercepted Message. This helps make sense of information sufficiency and information necessity, and we envision that elements of this report card will be available when inspecting nodes and links of SKYLINE's mission-level KG UI.

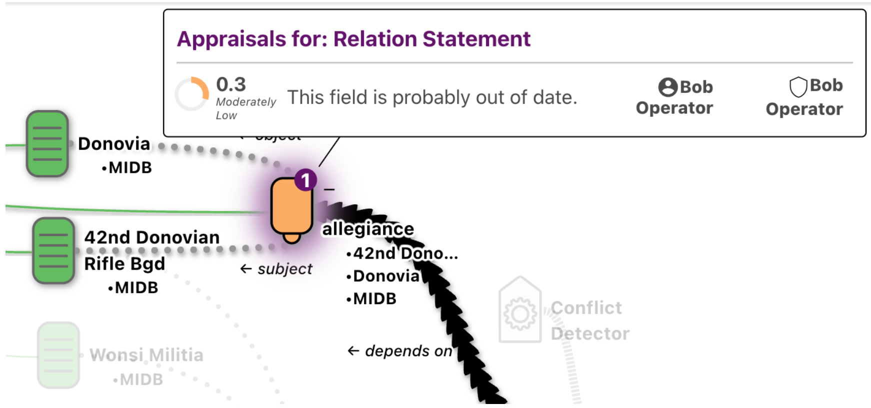

Figure 8: An appraisal by Bob Operator, ascribing low confidence to an MIDB record, and commenting that it may be outdated. Appraisals may be shared across many analyses, and they impact the estimated confidence in downstream conclusions.

Answering integrity questions of mission hypotheses. SKYLINE will use the interfaces shown above, in addition to others, to facilitate analyst sensemaking in complex data environments. It will help answer the following questions for any piece of content in SKYLINE's mission-level KG:

- ***How diverse (and independent) is the support for this inference?***: By traversing the provenance of inferences upstream, SKYLINE can identify sensors, reports, and collection disciplines that contributed to it, helping articulate the diversity, authority, sourcing, and corroboration of the conclusions [1, 2, 11].
- ***What assumptions, risks, and information gaps does this inference rely on?***: Humans and machines can make explicit assumptions about the world, and SKYLINE will identify these within the provenance and marshal them to the human analyst's attention. Unsupported assumptions could be risks or information gaps, or if an assumption will occur in the future, it could be a prediction and support subsequent collection goals.
- ***What impact has this (data source or inference) had on my analyses?***: SKYLINE will trace *forward* through the provenance to identify all information that has been derived from the given element, in order to assess how central it is to the mission. This is especially important for *damage assessment* (ICD 732) if a data source or record is later known to be deceptive or misleading.
- ***What if this (inference or source) was absent or different?***: SKYLINE will support counterfactual *"what-if"* questions (including sensitivity analyses) by both (1) displaying the result of disabling elements, as shown in Figure 7, thereby creating a hypothetical situation in provenance without damaging the integrity of the world state.
- ***How confident should I be of this inference?***: Machines should not make finished-intelligence confidence judgments, but as we show in Figure 9, we can bring upstream information (foundational sources, assumptions, etc.) to the analyst's attention while they manipulate the interactive KG, to ensure they understand the processes of analysis that underpin the mission-level content.
- ***What alternatives are there to this inference?***: The mission-level schema, e.g., from data sources like MIDB or MARS, dictate that some fields may only have one value, and alternative values may be alternative hypotheses. Our example in Figure 5 and Figure 6 shows one such pair of alternatives (for *allegiance*), and SKYLINE can flag these in the provenance (Figure 5, left) and display them in mission-level knowledge graphs (Figure 5, right).

Many of the above sensemaking activities are diagrammatic *"conversations"* between the human and

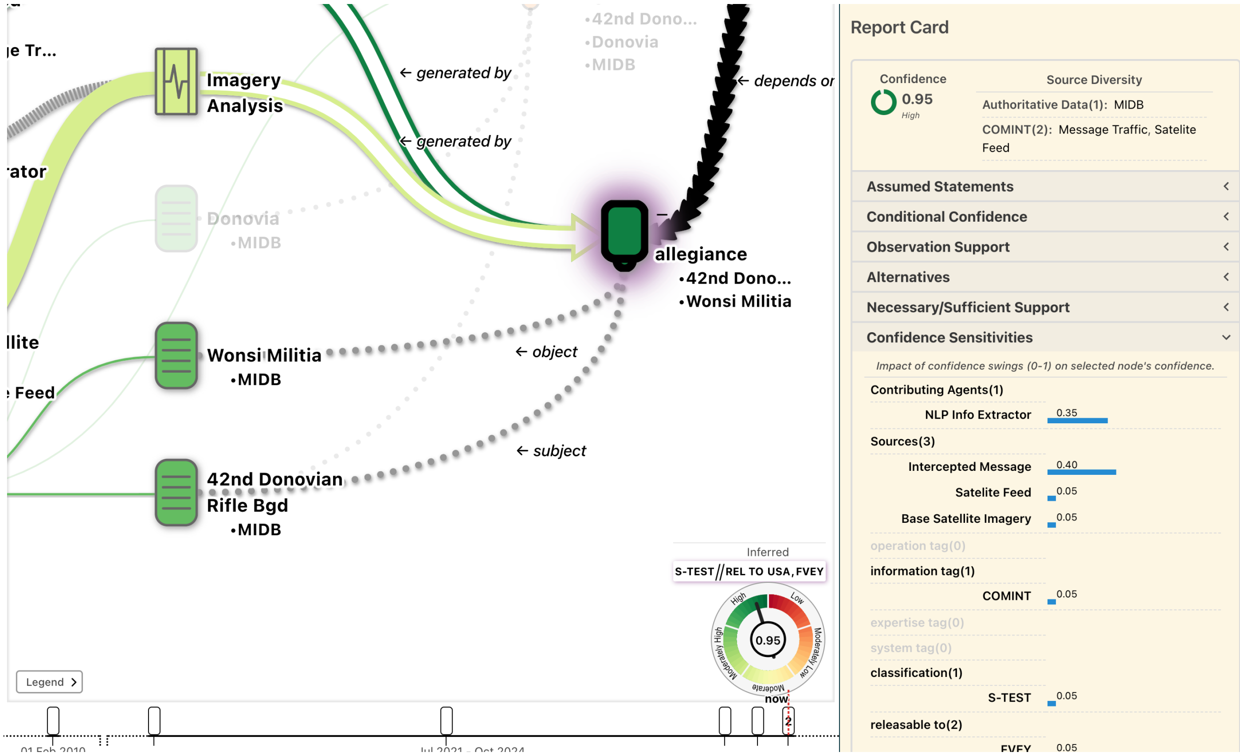

Figure 9: The "report card" displaying factors that impact a hypothesis' confidence, including a sensitivity analysis that shows the estimated confidence that is afforded by various sources, contributors, and collection disciplines.

machine, using the knowledge graph as a basis for shared human-machine perception of the intelligence analysis problem. SIFT will not need to make any improvements to the Project7 software under the SKYLINE SBIR effort, but we can utilize the data store and some pre-existing UIs to boost our productivity and prototyping early in Phase I.

2.6 Metrics for quality and success in interactive KGs

We propose to use current industry standard metrics to measure the quality of SKYLINE's machine inference, accuracy of priority rankings, and accuracy. We will use these metrics throughout the SKYLINE SBIR effort, but we expect some metrics (e.g., for human-machine team analysis) not to appear until Phase II. For each metric, we briefly provide its purpose and, when practical, an equation.

We first review metrics for machine inference. We plan to use these metrics to compare different algorithms and strategies, helping illustrate trade-offs in the performance space.

- ***Ground Truth***: Labels from human experts describing the behaviors, actions, and intents that the machine *should* predict or retrieve, such that all others are either irrelevant or incorrect. This is a type of data; it is not a metric, but it is used by the metrics below.
- ***Precision***: Fraction of positive machine predictions that are *actually* correct (i.e, in ground truth). This is a measure of *correctness* when an inference is made by the machine.
- ***Recall***: Fraction of ground truth (i.e., expected) predictions that are predicted by the machine. This is a measure of *completeness* or *coverage* of the machine inference capabilities.
- ***F1 Score***: The harmonic mean of precision p and recall r, to compactly report both values with a single score: $\mathrm{F1} = \frac{2pr}{p+r}$. We propose using F1 score to measure how well SKYLINE adds context

via the Contextual Detail Slider (§2.2) and how well SKYLINE identifies and labels tradecraft factors such as alternatives and sourcing alerts (§2.2, §2.5) in our evaluation.

- ***Mean Average Precision (MAP)***: A ranking quality metric that considers the number of relevant recommendations (i.e., from a ground-truth) and their position in a machine-generated ranking. We will use MAP to evaluate SKYLINE's priority feed of relevant information (§2.4).
- ***Efficiency***: Since time pressures are a central consideration in the IC with massive volumes of information, we envision tracking efficiency of the system in multiple regards: (1) *full inference duration* measures machine duration to make all relevant inferences until its termination condition, (b) *time to analytic milestone(s)* measures time to reach key solutions in the analysis, potentially using heuristics as shortcuts, and (c) *incremental utility* measures the proportion of correct or mission-relevant machine inferences over time. We will assess the efficiency of SKYLINE's provenance-based detection of tradecraft considerations in Phase I, but larger human-machine team efficiency metrics are important for later phases.
- ***Expressiveness***: Proportion of domain events, relations, goals, and tasks that are expressible in the knowledge graph. This measures the fit of the knowledge representation against the problem to be solved, allowing us to measure the fit of the KG against the mission, over time. We will assess expressiveness in Phase I.
- ***Workload and Usability***: Since the machine inference has to accommodate the needs and workflow of the user, we propose utilizing some existing instruments such as workload assessment using NASA's TLX, Situation Awareness using SART or SAGAT, and/or system usability using SUS. We will use these metrics in Phase II and beyond.
- ***Accessibility and Compliance with Directives***: Analytic tradecraft requires access to sources, assumptions, sensitivity, risk, conflicts, corroboration, alternatives, and more [1, 2, 11]. SIFT has measured this in the Project7 SBIR (§4.2) with (1) timed surveys of users' ability to identify these factors within an analysis and (2) subjective scalar assessments of information accessibility and trust in machine teammates. Measuring how well users characterize these tradecraft-relevant aspects of machine inferences will help us characterize how SKYLINE complements the analytic workflow. We will use these metrics in Phase II and beyond.

3 SKYLINE Phase I Work Plan (Non-Proprietary)

Scope. The SKYLINE Phase I SBIR effort will design, prototype, and demonstrate knowledge graph interaction in an all-source (i.e., Multi-INT) setting, with human and machine collaborators and full analytic provenance. We plan to use a mix of off-the-shelf data, SIFT-simulated data, and data from SIFT-generated vignettes that SIFT used for DIA's MARS program to demonstrate the integration of authoritative and emerging data for all-source analyses. The SKYLINE prototype we build in Phase I will focus on knowledge graph interaction, building on SIFT's existing graph-based reasoning and IC tradecraft interface. It will also leverage SIFT's NLP information extraction capabilities for demonstrative purposes. SIFT will rigorously evaluate the prototype to ensure the feasibility of our approach and characterize trade-offs.

The evaluations in Phase I will occur near the end of the effort, focusing on the expressivity, provenance capture, contextual information access, and priority rankings. We plan to engage prospective transition partners for briefings throughout the Phase I effort.

3.0.1 Task Outline: Phase I (6 months).

Below we describe each task and corresponding milestones. Figure 10 shows the schedule with milestones indicated by black triangles.

Requirements— SIFT will design the SkyLine specifications for human-machine team analysis with interactive knowledge graphs. The specifications will include user interface (UI) requirements and a taxonomy of user and machine KG interactions, e.g., manners in which the user can specify objectives for their machine teammates. We will also identify useful datasets—such as SIFT's Unclassified vignettes for DIA's MARS program, online message feeds, semantic web repositories like Wikidata[1] and DBPedia[2]—and generate synthetic data as needed to support the prototyping. SIFT will also incorporate datasets of interest from AFRL program management. These datasets and data-sources will support autonomous SkyLine agents that users can task with information-collection objectives via the knowledge graph UI. The design of SkyLine will comprise a significant portion of the SkyLine Phase I final report.

Design of Algorithms/User Experience (UX)— SIFT will prototype the SkyLine algorithms and user interactions, including a diverse set of user-to-machine directives (for collection, relevance) and tradecraft considerations (e.g., conflicts, alternative hypotheses, and elements with high or low confidence). *Milestones*: (1) **KG UI** produces a user interface (UI) display of semantic content in a knowledge graph, including semantic data and multiple types of user objectives (e.g., for relevance and collection tasks). (2) **Priority Queue** produces a prototype of the priority queue that displays ranked data that was extracted by machines—designed to avoid the inundation of new data—using the user's relevance objectives (from the KG UI milestone) to filter and prioritize new data.

Prototyping & Evaluation— SIFT will periodically evaluate SkyLine's human-machine interface and agent capabilities, using industry standard metrics for relevance-rankings and information retrieval as appropriate given the datasets and scenarios. SIFT will conduct demonstrations to gather formative feedback to guide the effort and advise the direction of a future SkyLine Phase II effort. *Milestones*: (1) **Prov Demo** demonstrates SkyLine's provenance capabilities, with an early integration with Project7 (§4.2). (2) **KG Demo** demonstrates the KG UI—and potentially agent responsiveness to collection tasks—for AFRL program management and potential transition customers for formative feedback. (3) **KG Eval** conducts a formal evaluation of the Phase I approach using the metrics we've identified (see Section 2.6 for a listing) under different operating assumptions, method choices, and knowledge states in order to illustrate trade-offs.

Reporting & Administration— SIFT will manage the direction of the program, write interim and final reports, and attend to research interests of AFRL program management. *Milestones*: (1) **Monthly reports** (see Deliverables); (2) **Final report** (see Deliverables).

Milestone Schedule. The SkyLine Phase I schedule overlaps requirements, algorithm/UX design, and prototyping to allow us to inform design-work with early prototype feedback. This is adjustable as desired by AFRL program management. Milestones are shown in the Figure 10 as black triangles in their respective tasks. We include a proposed trip to visit AFRL program management within the milestone schedule and also in the deliverables.

Deliverables. The SkyLine Phase I SBIR deliverables include:

- **Kickoff Meeting** with AFRL program management within 30 days of contract to discuss the effort.
- **Monthly Progress Reports** describing interim progress within each reporting period.
- **Interim Demonstration** of the prototype in or around months 4-5.
- **Final Program Review Meeting** with AFRL program management in the final month of Phase I.
- **Final Report with SF-298** summarizing SkyLine architecture, feasibility, lessons learned, trade-off analysis on the best technical development path, algorithm and method choice, data management

[1] https://www.wikidata.org/wiki/Wikidata:Main_Page
[2] https://www.dbpedia.org/resources/

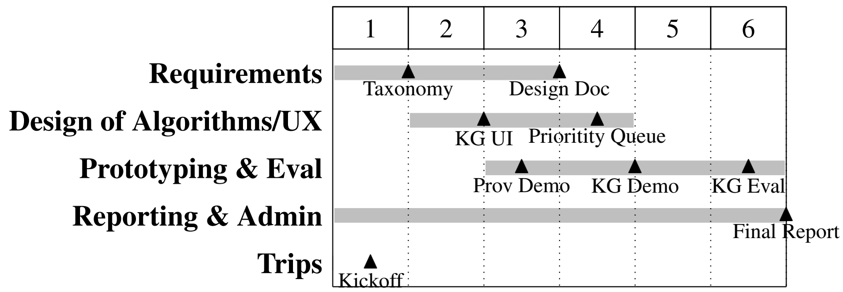

Figure 10: Monthly schedule for SKYLINE over the nine months of the effort.

and software framework decision, and potential risk and negation strategy. If desired, SIFT is also prepared to deliver a draft final report for AFRL program management review.

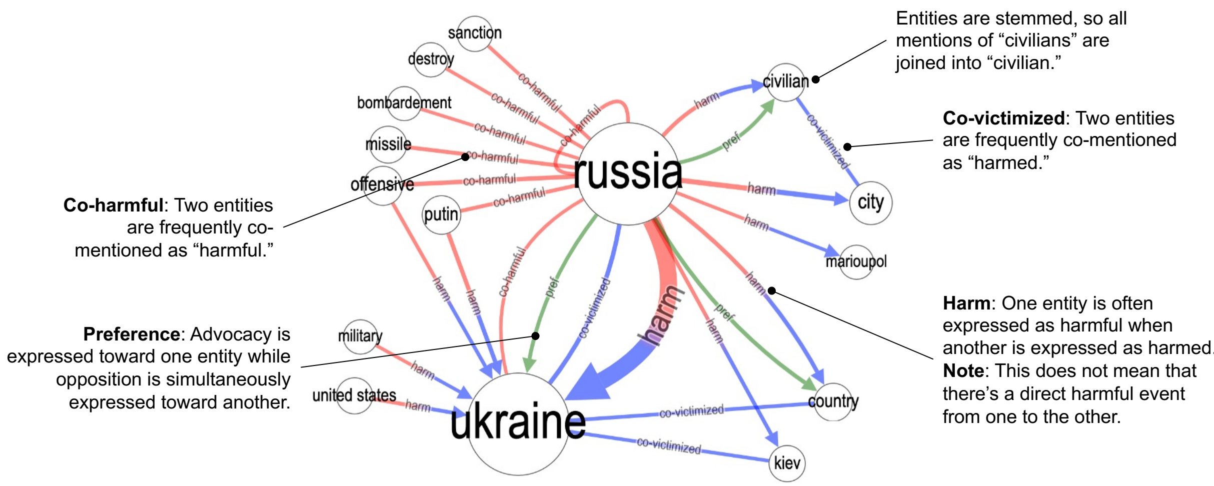

Figure 11: Thematic knowledge graph screenshot from SIFT's RADII tool for the DARPA INCAS program, with added call-outs. Each edge in the graph represents a listing of messages conforming to that theme (e.g., Russia harming Ukraine); clicking any displays the message feed for that theme.

4 Related Work

4.1 RADII: NLP Tools for Influence Operations

SIFT is developing RADII under the ongoing DARPA INCAS program (PoC: Dr. Victoria Romero, victoria.romero@darpa.mil), aimed at characterizing influence attempts over millions of online messages across platforms, languages, topics, and time. RADII is a micro-service architecture that includes a suite of containerized NLP tools—for assessing themes, regard, emotions, moral framing, narratives, and stance—and a knowledge-graph UI for visualizing and exploring the results. Figure 11 shows a knowledge graph plot of RADII's dyadic (i.e., pair-wise) themes, and Figure 12 shows a comparative sentiment density plot of two different topics over time. RADII is lead by SIFT's Dr. Chris Miller and Dr. Scott Friedman (§7.1).

SIFT's RADII tools have transitioned to the U.S. Department of State (PoC: Aaron Holm, HolmAL@state.gov) for inclusion in their Northstar system that will roll out to over 190 mission stations next year. RADII is also

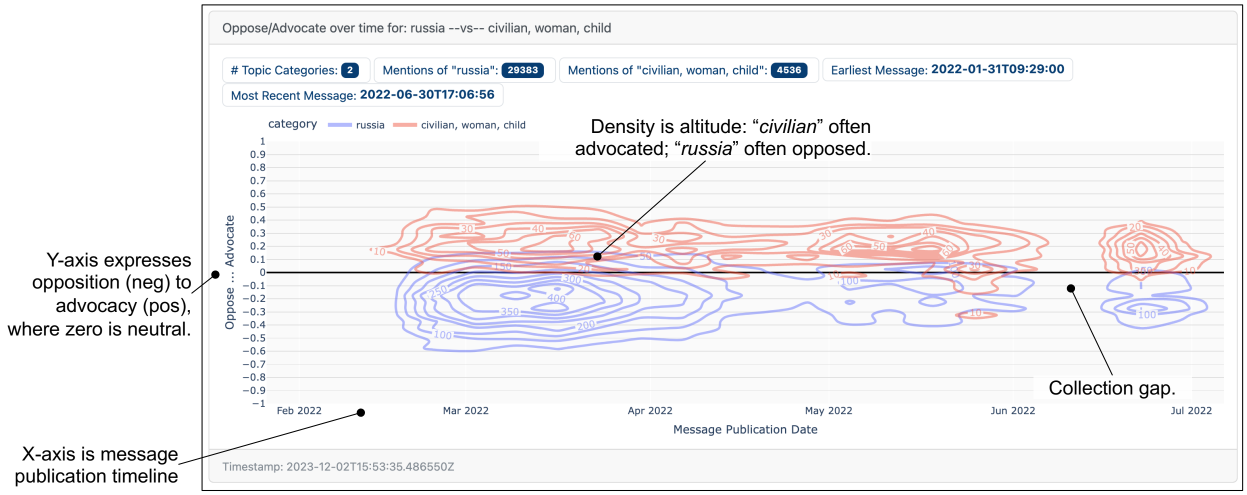

Figure 12: Timeline density plot from SIFT's Radii tool for the DARPA INCAS program, with added call-outs. This interactive density map compares messaging about Russia (in blue) vs. civilians, women, and children (in red). The x-axis is time, the y-axis is sentiment (positive and negative), and the altitude bands are density. Civilians are generally advocated, whereas Russia has peaks of opposition, especially near their invasion of Ukraine.

in active or near-term testing with three separate groups in the U.S. military, with potential for transition into a program of record.

⇒ **Transition Potential** Advances in SkyLine knowledge graph techniques could potentially be integrated into Radii along our existing technology transition paths, impacting how information operations (IO) analysts interact with machine teammates to specify IO objectives to machines and consume complex NLP results.

4.2 Project7, SIFT's Human-Machine Analysis Workspace

SIFT initially developed Project7 under SBIR efforts funded by AFRL 711 HPW (PoC: Dr. Kellie Turner, kellie.turner@us.af.mil). Project7's *shared human-machine perception*, allows both humans and machines to consume, assess, and add information in modalities that they natively understand, to maximize the flexibility, transparency, and trust of human-machine team intelligence analysis.

Figure 3 shows how Project7 achieves shared human-machine perception by mapping the content of analysts' displays—including maps, link diagrams, reports, tables, and provenance graphs—to semantic knowledge graph elements, supporting expressive, unambiguous communication and tasking. Figure 13 shows three such UIs—two geospatial and one tabular—that grounds semantic elements and user-provided sketches and annotations in machine-readable knowledge graphs.

One of the most valuable aspects of Project7 for military transition is the tracking of human-machine provenance for object-based production: whenever a machine or human produces an inference or hypothesis, Project7 associates the sources that were used, the inference that was produced, and the types of operations that occurred. Project7 thereby helps maintain a view of dependency, lineage, pedigree, sourcing, and reliability of information, facilitating compliance with Intelligence Community Directives (ICDs) [1, 2].

Project7 has been deployed on JWICS/Dev for processing TS/SCI mission data as part of the MARS program (§4.3), on RTX BBN servers, and on SIFT's internal cloud. It uses horizontally-scalable open-source data services: JanusGraph or Neo4j as its graph database, Elasticsearch as its document indexer, and

Cassandra as its broad column data store.

⇒ **Risk Mitigation** We propose for SkyLine to use Project7 as its knowledge graph and user interface solution, allowing the team to attend to the research challenges rather than infrastructure questions early in Phase I. This will also support SkyLine's technology transition to our existing customers.

Throughout the Project7 SBIR contracts, SIFT conducted briefings and demonstrations with AFRL 711 HPW/RHXM, NASIC, ACC, and DIA. The proposed SkyLine PI Dr. Scott Friedman (§7.1) was PI on the Gemini and Project7 SBIR efforts.

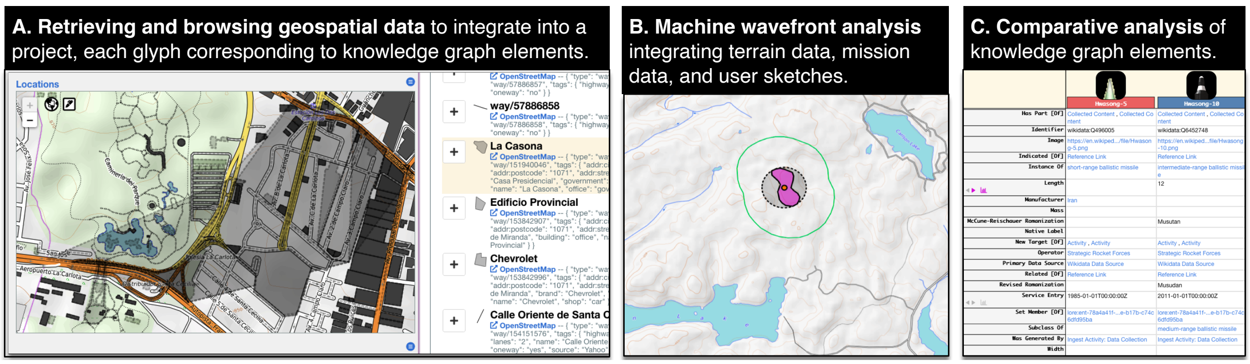

Figure 13: Project7 UIs: (a) browsing geospatial data about Caracas, including complex geometries, (b) sketch-based human-machine communication supporting machine wavefront analysis, and (c) comparative analysis of North Korean missiles automatically collected from Wikidata.

4.3 DIA MARS (Machine-Assisted Analytic Rapid-Repository System) Program

Building on success with the SBIR program, SIFT has won three programs from DIA to explore and migrate provenance advances to their MARS program that will transform MIDB (Modernized Integrated Database) with innovative human-machine analytics. The MARS program acquires technology to integrate novel approaches such as Project7's data model into all-source analysis, primarily tracking Order of Battle under many dimensions of uncertainty. All three of our MARS programs were lead by the SkyLine PI Dr. Scott Friedman (§7.1) and teamed with RTX BBN. MARS projects included: Comet (2019-2020, PoC John T Dillaplain, John.Dillaplain@dodiis.mil), an application of provenance technology on Unclassified data to demonstrate provenance-tracking many units over space and time with high-integrity; Colony (2021-2023, PoC Kathleen Todd, Kathleen.Todd2@dodiis.mil), which used provenance-based analyses to answer questions of confidence, data quality, counterfactuals, and distribution and release; and Consul (2021-2024, PoC Edward Clifton, Edward.Clifton@dodiis.mil), which tracked large-scale Order of Battle assessments, including the allegiance, equipment type, operational status, and locations of diverse assets, under uncertainty. All of these projects transitioned provenance-tracking approaches from Project7 and Radii, and both Colony and Consul were deployed to JWICS/Dev to process TS/SCI mission data.

SkyLine will leverage aspects of SIFT's MARS efforts, such as (1)provenance-tracking for high-integrity analyses and (2) containerization and security adjudication for military software transition. We plan to inform DIA customers about SkyLine advances to assess transition opportunities for human-machine teaming.

⇒ **Transition Potential** SkyLine knowledge graph technology could improve all-source analysis workflows that consume authoritative military data, e.g., from MIDB/MARS. Since SIFT helped design and demonstrate aspects of the MARS data model, SkyLine could be demonstrated to the MARS program office as an intuitive way for military users to visualize and consume authoritative data.

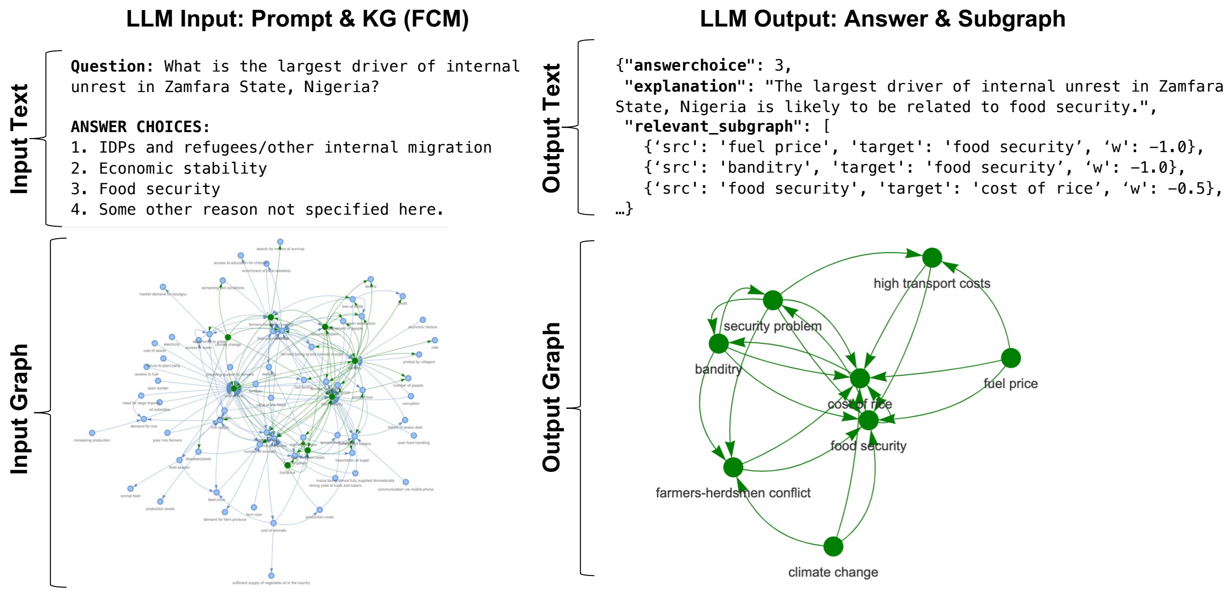

Figure 14: A dual-view of the input (left) and output (right) of a LLM query that includes both unstructured text and structured data (i.e., knowledge graph) in both its input and its output. This allows the LLM to use structured knowledge for context (e.g., a large causal graph, at left), and also contribute structured knowledge in its output (e.g., the subgraph that the LLM identifies as relevant to the problem-at-hand, at right).

4.4 DARPA HABITUS: Approaches for Structured Knowledge I/O for LLMs

Dr. Scott Friedman (§7.1) and Dr. Drisana Iverson (§7.2) lead SIFT's project for DARPA HABITUS (PoC: William Corvey), subcontracted by TwoSix Technologies for NLP and knowledge graph approaches. SIFT's HABITUS technology processes diverse datasets—ranging from Nigerian interviews about maternal and child health to Indonesian news articles about China's Belt and Road Initiative (BRI)—to extract fuzzy cognitive map (FCM) [3] knowledge graphs describing cause-and-effect and local beliefs. SIFT's approach uses LLMs to extract the structured knowledge graphs from news articles, social media, academic journals, and ethnographic interview transcripts.

More notably, Dr. Drisana Iverson devised an approach for mixed structured-and-unstructured interaction with LLMs, as shown in Figure 14. This allows us to read knowledge graphs into LLMs as context for queries and inference, and then have LLMs respond with structured knowledge outputs, e.g., to express additions, revisions, deletions, or relevant subgraphs of the knowledge graph. The knowledge graph is deterministically tokenized in the input, and then can be read out with constrained decoding, to ensure that the graph is specified with proper syntax and in the proper schema (i.e., only using the allowed nodes and edges). This is an important step in developing machine teammates to contribute to KG-based analyses.

4.5 CASCADE: Knowledge Graphs for DARPA Collaborative Knowledge Curation (CKC)

Dr. Matthew McLure (§7.3) leads SIFT's CASCADE project (DARPA I2O: Collaborative Knowledge Curation) that processes and consolidates a corpus of documents covering a domain of interest into a knowledge graph. CASCADE extracts and analyzes the latent structural similarities of documents' knowledge graphs, using a domain-specific graph schema for describing cases at multiple layers of granularity, clustering and indexing the documents using KG subgraphs. CASCADE empowers domain users to rapidly

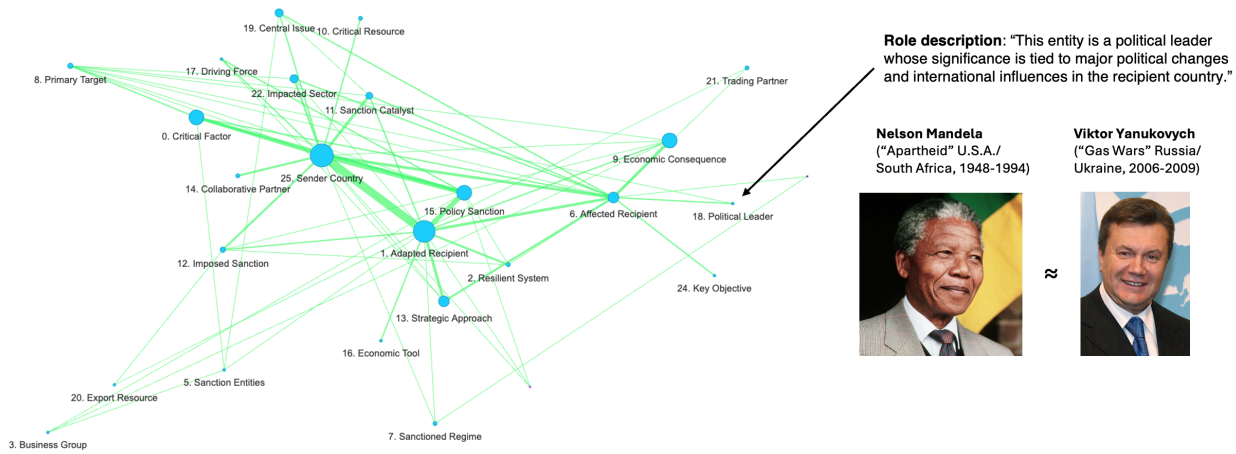

Figure 15: Screenshot of a knowledge graph in SIFT's CASCADE project for DARPA CKC.

observe the landscape of a new domain in either focused or exploratory use-cases. CASCADE incorporate recent advancements from ALIGN (§2.3.1) [10] and GraphRAG [27]—including hierarchical summarization and entity summaries—to generate a knowledge graph that is more expressive, concise and parsimonious. CASCADE avoids GraphRAG's reliance on domain-tailored prompts to incorporate domain-specific representations using comparative analysis (§2.3.1) [10] across cases to converge on a domain-relevant schema.

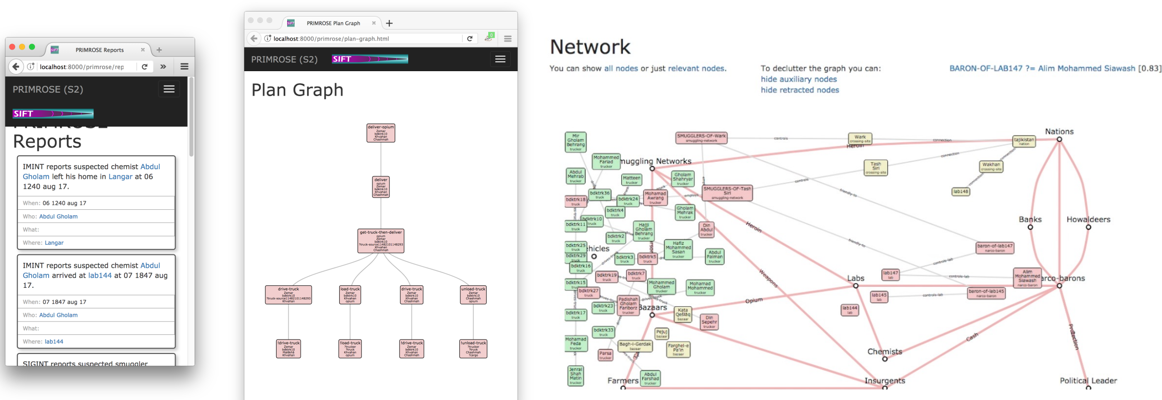

Figure 16: PRIMROSE takes unordered reports of events (left) to infer benign and adversarial plans (center) and populate network analysis diagrams of benign and adversarial behavior (right).

4.6 PRIMROSE: Plan Recognition for Intelligence Analysis

PRIMROSE (Figure 16) was a SIFT Phase I SBIR for the Defense Threat Reduction Agency, managed by Mr. William Young (william.t.young@leidos.com) and Dr. Donald Jones (donald.r.jones284.civ@mail.mil), led by SIFT's Dr. Robert Goldman and Dr. Scott Friedman. PRIMROSE applies probabilistic plan recognition, augmented by temporal, analogical, and provenance reasoning, to the challenge of network analysis for the intelligence community. In Phase I, PRIMROSE processed activity reports to (1) extract key entities (agents, equipment, locations, etc.), (2) use plan recognition to infer high-level goals and predict unobserved actions, (3) infer roles and relationships from observed and predicted behaviors, and (4) populate network analysis graphs [15]. Dr. Scott Friedman (§7.1) developed probabilistic KG-based inference for PRIMROSE, and PRIMROSE uses SIFT's Project7 as a knowledge management and user interaction platform, which provides evidence that Project7 can be leveraged to the same end in the SkyLine effort.

5 Relationship with Future Research and Development

If the SkyLine Phase I effort is successful, it will produce a design and prototype that will inform and mitigate the technical risk of a focused Phase II implementation effort. In its entirety, future phases of SkyLine could produce human-machine teaming paradigms that are facilitated by knowledge graphs, and augment U.S. analysts' reach and effectiveness across missions.

SkyLine will also improve SIFT's human-machine analysis technology (i.e., improving the breadth and depth of machine analysis capabilities) and also improve SIFT's machine inference technology (i.e., improving its interpretability and predictive capability). Since SIFT brings many existing components to SkyLine Phase I—including a knowledge graph analytic workspace (§4.2), other knowledge graph use-cases (§4.1, §4.6), and security-adjuticated containers for eventual classified deployments (§4.3)—we expect to be able to focus our Phase I effort on the principle technical challenges and the research interests of AFRL program management and transition partners.

The SIFT PI for SkyLine is cleared TS/SCI, and SIFT has additional cleared personnel at this level. SIFT's facilities are cleared at TS level. We do not anticipate additional clearances for the SkyLine effort, and all data proposed for use in Phase I is Unclassified. SIFT's CAGE code is 1NHZ1, and SIFT's Facilities Security Officer may be reached at fso@sift.net.

6 Commercialization Strategy

SIFT envisions dual-use technology transfer of SkyLine to analysts in both military and industry. We describe IC and cloud technology considerations (§6.1), the envisioned SkyLine dual customer base (§6.2) and then we describe our commercialization and market entry plan for rolling out SkyLine technology to military and industrial organizations, within and beyond the SkyLine SBIR effort (§6.3).

6.1 Commercialization: Supporting Technology

Through briefings and R&D efforts with the U.S. Intelligence Community (IC), SIFT understands the technology transition priorities, including horizontal and vertical scalability, cloud support, preference for actively-supported open-source software, and security considerations for deploying containerized software to JWICS servers. Consequently, the existing software that SIFT brings for the SkyLine effort as part of the Project7 package—including JanusGraph/Neo4j graph stores, Cassandra column store, Elasticsearch indexer, NodeJS UI servers, and Python-based analytics—have undergone DoD security adjudication and are compatible with Government cloud infrastructure. We have held tutorials for technologists in Raytheon/RTX, Lockheed Martin, and personnel in the DoD/IC for running SIFT's tools, and have already removed obstacles for deployment.

6.2 Commercialization: Customer Base

Military customer base. IC analysts face volumes of diverse intelligence data—including authoritative-but-dated information, emerging-but-raw information with uncertain pedigree, and intermediate intelligence from collaborators—and tremendous time pressures to solve complex intelligence problems, all while adhering to tradecraft standards. As described throughout this proposal, SkyLine will facilitate their mission by providing interactive mission-level KG (and spatiotemporal) displays that (1) visually coalesce information into [alternative] hypotheses, (2) help operators express objectives and tasks, and (3) track and visualize analytic provenance to explain tradecraft factors.

In the MARS technology acquisition program (§4.3), SKYLINE PI Dr. Scott Friedman briefed DIA analysts and tradecraft experts on a biweekly basis for three years, and under the AFRL Project7 SBIRs (§4.2), he briefed Air Combat Control (ACC) and National Air and Space Intelligence Center (NASIC) personnel semiannually for four years. These military customer engagements provided SIFT with feedback and insights for understanding agency-specific analytic tradecraft and improving the value of our analysis technology, while introducing the customers to new technology possibilities. Consequently, SKYLINE addresses real analytic standards, real metrics of rigor, and real data.

Corporate and law enforcement customer base. SKYLINE offers the ability to collect, organize, and visualize hypotheses—such as threats and indicators—in structured data, providing commercial customers the following abilities:

1. Assess and **forecast insider threat** by automatically processing financial events, security-relevant events, and communications with known bad actors.
2. Assess **patterns of life of criminal elements** and assemble data collected from metropolitan sources into a common operating picture.

The SKYLINE effort will not specifically improve NLP capabilities and source-specific analysis capabilities, but it provides human-machine interaction patterns where AI-based agents can "plug into" the analysis and field SKYLINE-specified tasking.

In addition to threat intelligence, competitive intelligence tools—including AI and information collection tools to gain insights about competitor behavior—reached USD $37.6 Million in 2019 and is estimated to Reach USD $82 Million by 2027.[3] SKYLINE's ability to transform observations into interpretable, actionable inferences of competitors' intentions and goals will also generalize from military actions into the domains of logistics and market analysis.

6.3 Commercialization: Market Entry Plan

SIFT will prioritize technology transfer to military customers, leveraging our previous technology transfer relationships (§4.3). We will also assess transition of SKYLINE to users in ACC and NASIC. We believe that ACC and NASIC transition will be consistent with our work with MARS, since MARS (MIDB's replacement) will be utilized by many IC agencies. Toward this end, we would appreciate AFRL program management facilitating engagements with ACC and NASIC within Phase I and throughout Phase II, as the program progresses.

SIFT will use successful results from Phase II to attract additional transition partners, such as RTX, Northrup Grumman, and Lockheed Martin, all of which SIFT has partnered with in the past, to explore technology licensing and collaborative R&D.

While SIFT pursues technology transition, we will purse patents on SKYLINE technology, building on our recently-allowed Project7 AFRL SBIR patent 16/948,297 for provenance-guided analytics to patent the proposed SKYLINE approach to provenance-backed situational knowledge graphs. We will pursue a provisional patent early in Phase I and then a full patent before the start of a prospective Phase II SBIR effort. These patents will support technology licensing, which will also attract venture capitalists and contribute to commercialization potential, while allowing the U.S. Government to utilize the technology.

[3] https://www.globenewswire.com/news-release/2021/10/11/2311529/0/en/Competitive-Intelligence-Tools-Market-to-Develop-Fundamentally-Growing-Popularity-of-AI-powered-Competitive-Tools-to-Foster-Growth-states-Fortune-Business-Insights.html

Table 1: Summary of Financial Projections

	2026	2027	2028	2029	2030
Follow-On R&D Contracts	$250,000	$500,000	$500,000	$750,000	$750,000
Integrator upfront license fees	$500,000	$500,000	$500,000	$-	$-
Commercial Royalties	$-	$50,000	$500,000	$12,500,000	$20,500,000

Success in the DoD market will allow us to attract venture capitalists to market our software as an industrial threat- and competitor-analysis tool, as described above. The rapid growth in the market over the next five years makes the adoption of SKYLINE technology much more likely as competitors look for new technology to distinguish their product.

SIFT engaged Brimacomb & Associates (www.brimacomb.com) and RTI, firms that aid startups to obtain venture capital funding, to develop SIFT's commercialization strategy and provide us realistic estimates on revenue for new products. Table 1 shows our financial projections for SKYLINE based on our discussions with these groups. Table 1 assumes an additional $750K in funding beyond SKYLINE Phase II. The funding will either come from further DoD contracts with SIFT teamed with a large integrator, or internal integrator funds, which we have received in the past from Lockheed Martin.

SIFT has a history of leveraging SBIR projects to seed additional R&D contracts from government or commercial partners, which we also account for in Table 1, increasing over time as SKYLINE improves SIFT's intelligence analysis and human-machine teaming portfolio.

7 Key Personnel (All personnel are U.S. citizens)

7.1 Dr. Scott Friedman, SIFT Research Fellow, SKYLINE PI

- Ph.D., Computer Science, Northwestern University, 2012.
- B.S. / M.S., Computer Science, Washington University in St. Louis, 2003 / 2005.

Dr. Friedman is a Research Fellow at SIFT specializing in AI, Machine Learning, and Cognitive Science with over 15 years of experience in applied AI R&D. He has authored over 70 publications and book chapters in AI/ML, human-machine team analysis, cognitive science, and cybersecurity, and has authored three SBIR-funded patents. His research interests include NLP [28, 29, 30], human-machine collaborative analysis [7, 15], provenance [14, 8], graph and pattern-matching [10], and automated planning and plan recognition [9, 15]. He is a reviewer and program committee for AI Journal, AAAI, EMNLP, NeurIPS, CogSci, Advances in Cognitive Systems, and Informatica, and he chaired the 2015 Workshop on Qualitative Reasoning. He has delivered invited talks for NATO's Human Factors and Medicine panel (RTO-HFM 330), the DoD Human Factors Technology Advisory Group, University of Minnesota, and University of Florida.

He is presently SIFT's PI on DARPA HABITUS, Co-PI on DARPA INCAS, and recently PI on SIFT's Project7 SBIR efforts (§4.2) funded by AFRL, resulting in an AFRL SBIR Success Story at the 2021 Human Systems COI Annual Meeting. He was also PI on two successful technology transition programs that transitioned Project7 to JWICS/Dev mission environments under DIA's MARS technology acquisition program (§4.3). He previously led NLP efforts for DARPA Understanding Group Bias, DARPA Big Mechanism, and DARPA CWC projects. Before joining SIFT in 2012, he received university graduate fellowships, including a Cognitive Science Advanced Graduate Research Fellowship to support his dissertation research on large-scale belief revision and knowledge representation in scientific domains.

Dr. Friedman holds a TS/SCI clearance. A complete list of publications is listed on his website,[4] but some relevant publications include:

[4] http://sites.google.com/site/scottfriedmanresearch

- S. E. Friedman, J. Rye, M. McLure, H. C. Wauck, P. Patel, R. Wheelock, M. A. Valovage, S. Johnston, and C. Miller. (2021). Provenance as a substrate for human sensemaking and explanation of machine collaborators. *IEEE SMC*. 1014-–1019.
- S. Friedman, M. Burstein, D. McDonald, R. Rosewall, and J. Benton. (2016). Strider: Toward an AI collaborator for intelligence analysis. *IJCAI Cognitive Computation Workshop*.
- S. E. Friedman, R. P. Goldman, R. G. Freedman, U. Kuter, C. Geib, and J. Rye. (2020). Provenance-based assessment of plans in context. *ICAPS Workshop on Explainable AI Planning*.
- R. P. Goldman, S. E. Friedman, and J. Rye. (2018). Plan recognition for network analysis: preliminary report. *AAAI Workshop on Plan, Activity, and Intent Recognition*, Munich, Germany, pp. 8–14.
- M. D. McLure, S. E. Friedman, and K. D. Forbus. (2015). Extending analogical generalization with near-misses. *Proceedings of AAAI*. pp.565– 571.
- S. E. Friedman, J. Rye, D. La Vergne, D. Thomsen, M. Allen, and K. Tunis, (2020). Provenance-based interpretation of multi-agent information analysis. *Proceedings of the 12th USENIX Conference on Theory and Practice of Provenance*.

7.2 Dr. Drisana Iverson (Mosaphir), SKYLINE Autonomy Lead

- Ph.D., Mathematics, University of Minnesota, 2022
- B.A., Applied Mathematics, Harvard University, 2017

Dr. Drisana Iverson is a Researcher at SIFT specializing in AI, Machine Learning, and modeling. Her research interests include NLP, applications of LLMs/image generation models, optimization, and verification of mathematical model properties. She is presently SIFT's PI on Phase II of an annotation/data collection project with JIGSAW, and recently SIFT's PI on DARPA Civil Sanctuary, where she contributed to the creation of a user interface and plugin for online forum moderation and human subjects research to evaluate the effectiveness of moderation strategies. She has also contributed NLP efforts to DARPA HABITUS, which included automated reasoning over knowledge graphs, and has contributed both to SIFT's SMT solver-based tools and design of a UI for scientific stakeholders in DARPA ASKEM.

More information is listed on her SIFT staff website.[5]

7.3 Dr. Matthew McLure, SKYLINE Knowledge Graph Learning Lead

- Ph.D., Artificial Intelligence, Northwestern University, 2019.
- B.S., Computer Engineering, Pennsylvania State University, 2009.

Dr. Matthew McLure is a Research Scientist at SIFT with over 10 years of experience in Artificial Intelligence, primarily graph-based learning and compression [10, 31], novelty detection [32], and qualitative spatial representations and reasoning [33, 34]. He completed his Ph.D. in Artificial Intelligence from Northwestern University, where he was a member of the Qualitative Reasoning Group. His thesis work, funded by AFOSR, developed an AI system that learned to recognize sketched objects given few training examples using analogical learning and hierarchical spatial processing, and even sketch novel instances of learned concepts using constraint satisfaction based on spring systems. He has served as a reviewer and program committee member CogSci and Advances in Cognitive Systems.

At SIFT, Dr. McLure is PI on the CASCADE project for DARPA (§4.5), he leads hypothesis-based reasoning R&D for DARPA's ShELL project, and he led geospatial and network analyses for SIFT's DIA MARS programs (§4.3), where he has also helped develop the user interface. Dr. McLure is also a contributor to DARPA's SAIL-ON where his work has produced new domain-general novelty detection methods, and he has contributed to DARPA's HABITUS and INCAS projects.

8 Foreign Citizens

This project involves no foreign citizens or dual citizenship holders.

[5] `https://www.sift.net/staff/drisana-iverson`

9 Facilities

SIFT will conduct the work at SIFT's facility in Minneapolis, Minnesota, which holds a TS facility clearance. SIFT maintains a leading-edge computer network—including an internal cloud with Kubernetes support, multiple GPU servers, and web services support—providing the requisite development environment for SKYLINE and other applications, from AI to conventional software engineering environments. SIFT's facilities meet all applicable federal, state, and local government regulations, including all environmental laws and regulations. We will not acquire additional equipment under this effort.

10 Subcontractors/Consultants

No consultants will be used on SKYLINE.

11 Prior, Current, or Pending Support

No prior, current, or pending support for proposed work.

References

[1] Director of National Intelligence, "Intelligence community directive 203: Analytic standards," January 2015.

[2] Director of National Intelligence, "Intelligence community directive 206: Sourcing requirements for disseminated analytic products," January 2015.

[3] S. A. Gray, E. Zanre, and S. R. Gray, "Fuzzy cognitive maps as representations of mental models and group beliefs," in *Fuzzy cognitive maps for applied sciences and engineering: From fundamentals to extensions and learning algorithms*, pp. 29–48, Springer, 2013.

[4] CIA, "Structured analytic techniques for improving intelligence analysis," *CIA Center for the Study of Intelligence*, 2009.

[5] R. J. Heuer, *Psychology of intelligence analysis*. Lulu.com, 1999.

[6] E. Budlong, C. Pine, M. Zappavigna, J. Homer, C. Proefrock, J. Gucwa, M. Crystal, and R. Weischedel, "Interactive information extraction and navigation to enable effective link analysis and visualization of unstructured text," in *Proceedings of the AAAI Conference on Artificial Intelligence*, vol. 27, pp. 1493–1500, 2013.

[7] S. Friedman, M. Burstein, D. McDonald, R. Rosewall, and J. Benton, "Strider: Toward an ai collaborator for intelligence analysis," in *Proceedings of the IJCAI Cognitive Computation Workshop*, 2016.

[8] S. E. Friedman, J. Rye, M. McLure, H. C. Wauck, P. Patel, R. Wheelock, M. A. Valovage, S. Johnston, and C. Miller, "Provenance as a substrate for human sensemaking and explanation of machine collaborators," in *2021 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*, pp. 1014–1019, IEEE, 2021.

[9] S. E. Friedman, R. P. Goldman, R. G. Freedman, U. Kuter, C. Geib, and J. Rye, "Provenance-based assessment of plans in context," *ICAPS Workshop on Explainable AI Planning*, 2020.

[10] M. D. McLure, S. E. Friedman, and K. D. Forbus, "Extending analogical generalization with near-misses.," in *AAAI*, pp. 565–571, 2015.

[11] D. J. Zelik, E. S. Patterson, and D. D. Woods, "Measuring attributes of rigor in information analysis," *Macrocognition metrics and scenarios: Design and evaluation for real-world teams*, pp. 65–83, 2010.

[12] D. T. Moore, *Sensemaking: A structure for an Intelligence Revolution*. Government Printing Office, 2013.

[13] L. Moreau, B. Clifford, J. Freire, J. Futrelle, Y. Gil, P. Groth, N. Kwasnikowska, S. Miles, P. Missier, J. Myers, *et al.*, "The open provenance model core specification (v1. 1)," *Future generation computer systems*, vol. 27, no. 6, pp. 743–756, 2011.

[14] S. Friedman, J. Rye, D. La Vergne, D. Thomsen, M. Allen, and K. Tunis, "Provenance-based interpretation of multi-agent information analysis," in *Proceedings of the 12th USENIX Conference on Theory and Practice of Provenance*, 2020.

[15] R. Goldman, S. Friedman, and J. Rye, "Plan recognition for network analysis: preliminary report," in *Proceedings of the AAAI 2018 Workshop on Plan, Activity, and Intent Recognition, Munich, Germany*, pp. 8–14, 2018.

[16] Y. Yan, L. Liu, Y. Ban, B. Jing, and H. Tong, "Dynamic knowledge graph alignment," in *Proceedings of the AAAI conference on artificial intelligence*, vol. 35, pp. 4564–4572, 2021.

[17] Z. Huang, Z. Li, H. Jiang, T. Cao, H. Lu, B. Yin, K. Subbian, Y. Sun, and W. Wang, "Multilingual knowledge graph completion with self-supervised adaptive graph alignment," *arXiv preprint arXiv:2203.14987*, 2022.

[18] J. H. Brenas and A. Shaban-Nejad, "Proving the correctness of knowledge graph update: a scenario from surveillance of adverse childhood experiences," *Frontiers in big Data*, vol. 4, p. 660101, 2021.

[19] M. Nečaský and Štěpán Stenchlák, "Interactive and iterative visual exploration of knowledge graphs based on shareable and reusable visual configurations," *Web Semantics*, vol. 73, p. 100713, jul 2022.

[20] H. Vargas, C. Buil-Aranda, A. Hogan, and C. López, "Rdf explorer: A visual sparql query builder," in *The Semantic Web – ISWC 2019: 18th International Semantic Web Conference, Auckland, New Zealand, October 26–30, 2019, Proceedings, Part I*, (Berlin, Heidelberg), p. 647–663, Springer-Verlag, 2019.

[21] T. Ehrhart, P. Lisena, and R. Troncy, "Kg explorer: a customisable exploration tool for knowledge graphs," in *VOILA 2021, International Workshop on the Visualization and Interaction for Ontologies and Linked Data*, 2021.

[22] A. M. Collins and E. F. Loftus, "A spreading-activation theory of semantic processing.," *Psychological review*, vol. 82, no. 6, p. 407, 1975.

[23] F. Crestani, "Application of spreading activation techniques in information retrieval," *Artificial Intelligence Review*, vol. 11, pp. 453–482, 1997.

[24] D. Aswath, S. T. Ahmed, J. D'cunha, and H. Davulcu, "Boosting item keyword search with spreading activation," in *The 2005 IEEE/WIC/ACM International Conference on Web Intelligence (WI'05)*, pp. 704–707, IEEE, 2005.

[25] K. D. Forbus, R. W. Ferguson, A. Lovett, and D. Gentner, "Extending sme to handle large-scale cognitive modeling," *Cognitive Science*, vol. 41, no. 5, pp. 1152–1201, 2017.

[26] T. Lebo, S. Sahoo, D. McGuinness, K. Belhajjame, J. Cheney, D. Corsar, D. Garijo, S. Soiland-Reyes, S. Zednik, and J. Zhao, "PROV-O: The PROV Ontology," *W3C recommendation*, vol. 30, 2013.

[27] D. Edge, H. Trinh, N. Cheng, J. Bradley, A. Chao, A. Mody, S. Truitt, and J. Larson, "From local to global: A graph rag approach to query-focused summarization," *arXiv preprint arXiv:2404.16130*, 2024.

[28] S. Friedman, N. Benkler, D. Mosaphir, J. Rye, S. Schmer-Galunder, M. Goldwater, M. McLure, R. Wheelock, J. Gottlieb, R. Goldman, and C. Miller, "Bottom-Up and Top-Down Analysis of Values, Agendas, and Observations in Corpora and LLMs," *NeurIPS Workshop on Pluralistic Alignment*, 2024.

[29] J. Zheng, S. Friedman, S. Schmer-Galunder, I. Magnusson, R. Wheelock, J. Gottlieb, D. Gomez, and C. Miller, "Toward a theory-based model for characterizing directed social regard in online messaging," pp. 203–208, 2022.

[30] S. Friedman, J. Zheng, and H. Steinmetz, "Debiasing multi-entity aspect-based sentiment analysis with norm-based data augmentation," in *Proceedings of the 2024 Joint International Conference on Computational Linguistics, Language Resources and Evaluation (LREC-COLING 2024)*, pp. 4456–4461, 2024.

[31] M. McLure, S. Kandaswamy, and K. Forbus, "Finding textures in sketches using planar ising models," in *28th International Workshop on Qualitative Reasoning (QR2015)*, 2015.

[32] M. D. McLure and D. M. Musliner, "A changepoint method for open-world novelty detection," *2022 IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2022)*, in press.

[33] M. McLure and K. Forbus, "Encoding strategies for learning geographical concepts via analogy," in *Proceedings of the Twenty-Sixth International Workshop on Qualitative Reasoning*, 2012.

[34] M. D. McLure, S. E. Friedman, A. Lovett, and K. D. Forbus, "Edge-cycles: A qualitative sketch representation to support recognition," in *Proceedings of the 25th International Workshop on Qualitative Reasoning*, 2011.

DSIP Defense SBIR/STTR Innovation Portal

Cost Volume

SBIR Phase I Proposal

Proposal Number	F244-0001-0028
Topic Number	AF244-0001
Proposal Title	SkyLine: Structured Knowledge Graphs with Integrity & Lineage
Date Submitted	11/05/2024 05:14:05 PM

Firm Information

Firm Name	Smart Information Flow Technologies, d/b/a SIFT
Mail Address	319 1st Ave North Suite 400, Minneapolis, Minnesota, 55401
Website Address	http://www.sift.net
UEI	HT19FEFNVXC5
Duns	103477993
Cage	1NHZ1

Total Dollar Amount for this Proposal	$139,481.78
Base Year	$139,481.78
Year 2	$0.00
Technical and Business Assistance(TABA)- Base	$0.00
TABA- Year 2	$0.00

Base Year Summary

Total Direct Labor (TDL)	$83,915.96
Total Direct Material Costs (TDM)	$0.00
Total Direct Supplies Costs (TDS)	$0.00
Total Direct Equipment Costs (TDE)	$0.00
Total Direct Travel Costs (TDT)	$1,406.00
Total Other Direct Costs (TODC)	$0.00
G&A (rate 49.43%) x Base (TDL+TOH)	$41,479.66
Total Firm Costs	$126,801.62
Subcontractor Costs	
Total Subcontractor Costs (TSC)	$0.00
Cost Sharing	-$0.00
Profit Rate (10%)	$12,680.16
Total Estimated Cost	$139,481.78
TABA	$0.00

Year 2 Summary

Total Direct Labor (TDL)	$0.00
Total Direct Material Costs (TDM)	$0.00

Total Direct Supplies Costs (TDS)	$0.00
Total Direct Equipment Costs (TDE)	$0.00
Total Direct Travel Costs (TDT)	$0.00
Total Other Direct Costs (TODC)	$0.00
G&A (rate 49.43%) x Base (TDL+TOH)	$0.00
Total Firm Costs	$0.00
Subcontractor Costs	
Total Subcontractor Costs (TSC)	$0.00
Cost Sharing	-$0.00
Profit Rate (10%)	$0.00
Total Estimated Cost	$0.00
TABA	$0.00

Base Year

Direct Labor Costs

Category / Individual-TR	Rate/Hour	Estimated Hours	Fringe Rate (%)	Fringe Cost	Cost
Computer and Information Research Scientist/ Principal Investigator (Scott Friedman)	$132.58	132			$17,500.56
Computer and Information Research Scientist/ Researcher (Drisana Iverson)	$67.91	269			$18,267.79
Computer and Information Research Scientist/ Researcher (Matt McLure)	$67.91	249			$16,909.59

Subtotal Direct Labor (DL)	$52,677.94
Labor Overhead (rate 59.3%) x (DL)	$31,238.02
Total Direct Labor (TDL)	**$83,915.96**

Direct Travel Costs

Project Kickoff	$1,406.00
Total Direct Travel Costs (TDT)	**$1,406.00**

G&A (rate 49.43%) x Base (TDL+TOH)	$41,479.66
Cost Sharing	-$0.00
Profit Rate (10%)	$12,680.16
Total Estimated Cost	$139,481.78
TABA	$0.00

Year 2

Direct Labor Costs						
	Category / Individual-TR	Rate/Hour	Estimated Hours	Fringe Rate (%)	Fringe Cost	Cost
	Computer and Information Research Scientist/ Principal Investigator (Scott Friedman)	$132.58	0			$0.00
Subtotal Direct Labor (DL)						$0.00
Labor Overhead (rate 59.3%) x (DL)						$0.00
Total Direct Labor (TDL)						**$0.00**

Direct Travel Costs

N/A	$0.00
Total Direct Travel Costs (TDT)	**$0.00**

G&A (rate 49.43%) x Base (TDL+TOH)	$0.00
Cost Sharing	-$0.00
Profit Rate (10%)	$0.00
Total Estimated Cost	$0.00
TABA	$0.00

Explanatory Material Relating to the Cost Volume

The Official From the Firm that is responsible for the cost breakdown

Name: Scott Friedman

Phone: (314) 640-9077

Phone: sfriedman@sift.net

Title: Proposal Owner

If the Defence Contracting Audit Agency has performed a review of your projects within the past 12 months, please provide: Yes

Audit Agency Name: DCAA, Minneapolis Branch Office

Audit Agency POC: Melissa Scherf

Address: 316 Robert St N, STE 615, St. Paul, Minnesota,55101

Phone: (763) 744-5520

Email: Melissa.Scherf@dcaa.mil

Select the Type of Payment Desired: Partial payments

Cost Volume Details

Direct Labor

Base

Category	Description	Education	Yrs Experience	Hours	Rate	Fringe Rate	Total
Computer and Information Research Scientist	Principal Investigator	PhD	20	132	$132.58		$17,500.56
Computer and Information Research Scientist	Researcher	PhD	7	269	$67.91		$18,267.79
Computer and Information Research Scientist	Researcher	PhD	13	249	$67.91		$16,909.59

Are the labor rates detailed below fully loaded? **NO**

Provide any additional information and cost support data related to the nature of the direct labor detailed above.
Direct labor costs are estimated using an avg hourly rate for each labor grade in FY2025 with a 3.5% escalation for each year thereafter, which is a combo of cost of living and merit-based increases.

Direct Labor Cost ($): $52,677.94

Year2

Category	Description	Education	Yrs Experience	Hours	Rate	Fringe Rate	Total
Computer and Information Research Scientist	Principal Investigator	PhD	20	0	$132.58		$0.00

Are the labor rates detailed below fully loaded? **NO**

Provide any additional information and cost support data related to the nature of the direct labor detailed above.
Direct labor costs are estimated using an avg hourly rate for each labor grade in FY2025 with a 3.5% escalation for each year thereafter, which is a combo of cost of living and merit-based increases.

Direct Labor Cost ($): $0.00

Sum of all Direct Labor Costs is($): $52,677.94

Overhead

Base

Labor Cost Overhead Rate (%)	**59.3**
Apply Overhead to Direct Travel Cost?	**NO**

Overhead Comments:
Provisional Billing Rates, approved by DCAA on 8/14/24, are used for cost estimation for this proposal because SIFT has historically very stable wrap rates. These are the same wrap rates that have been used for the past nine years, and approved by DCAA each year.

Overhead Cost ($):	**$31,238.02**

Year2

Labor Cost Overhead Rate (%)	**59.3**
Apply Overhead to Direct Travel Cost?	**NO**

Overhead Comments:
Provisional Billing Rates, approved by DCAA on 8/14/24, are used for cost estimation for this proposal because SIFT has historically very stable wrap rates. These are the same wrap rates that have been used for the past nine years, and approved by DCAA each year.

Overhead Cost ($):	**$0.00**
Sum of all Overhead Costs is ($):	**$31,238.02**

General and Administration Cost

Base

G&A Rate (%):	**49.43**
Apply G&A Rate to Overhead Costs?	**YES**
Apply G&A Rate to Direct Labor Costs?	**YES**
Apply G&A Rate to ODC- Travel?	**NO**

Please specify the different cost sources below from which your company's General and Administrative costs are calculated.
Provisional Billing Rates, approved by DCAA on 8/14/24, are used for cost estimation for this proposal because SIFT has historically very stable wrap rates. These are the same wrap rates that have been used for the past nine years, and approved by DCAA each year.

G&A Cost ($): **$41,479.66**

Year2

G&A Rate (%): **49.43**

Apply G&A Rate to Overhead Costs? **YES**

Apply G&A Rate to Direct Labor Costs? **YES**

Apply G&A Rate to ODC- Travel? **NO**

Please specify the different cost sources below from which your company's General and Administrative costs are calculated.
Provisional Billing Rates, approved by DCAA on 8/14/24, are used for cost estimation for this proposal because SIFT has historically very stable wrap rates. These are the same wrap rates that have been used for the past nine years, and approved by DCAA each year.

G&A Cost ($): **$0.00**

Sum of all G&A Costs is ($): **$41,479.66**

ODC-Travel

Base

Description: Project Kickoff

Location From: MInneapolis, MN

Location To: Rome, NY

Number of People: 2

Number of Days: 2

Purpose of Trip:
Project Kickoff

Total Airfare Costs ($): $892.00

Total Car Rental Costs ($): $90.00

Total Per Diem Costs ($): $424.00

Total Other Costs ($): $0.00

Total Costs ($): $1,406.00

Purpose of Trip:
Project Kickoff

Sources of Estimates:
Air quotes from Orbitz.com reflect the lowest available nonstop fare with no change fee. Per Diem rates are per published rates at http://www.gsa.gov. First and last day M&IE Per Diem is at 75%.

Explanation/Justifications: Annual travel escalation rates used in the proposal vary from 2.8% to 5.3% depending on the item (airfare, auto, etc.). We consider the Consumer Price Indexes for All Urban Consumers, Transportation-Related Goods and Services when setting escalation rates. The increase in overall transportation from 2020 to 2021 was 14.6% and 2021 to 2022 was 32.3%, which suggest we've been conservative in our estimates.

Year2

Description: N/A

Location From: N/A

Location To: N/A

Number of People: 0

Number of Days: 0

Purpose of Trip:
N/A

Total Airfare Costs ($): $0.00

Total Car Rental Costs ($): $0.00

Total Per Diem Costs ($): $0.00

Total Other Costs ($): $0.00

Total Costs ($): $0.00

Purpose of Trip:
N/A

Sources of Estimates:
N/A

Explanation/Justifications: N/A

ODC-Summary

Base

Do you have any additional information to provide? **NO**

Year2

Do you have any additional information to provide? **NO**

Profit Rate/Cost Sharing

Base

Cost Sharing ($): **-**

Cost Sharing Explanation:

Profit Rate (%): **10**

Profit Explanation:
As a small business, SIFT's typical 10% fee is included in this proposal.

Total Profit Cost ($): **$12,680.16**

Year2

Cost Sharing ($):	**-**
Cost Sharing Explanation:	
Profit Rate (%):	**10**
Profit Explanation: **As a small business, SIFT's typical 10% fee is included in this proposal.**	
Total Profit Cost ($):	**$12,680.16**
Total Proposed Amount ($):	**$139,481.78**

SMART INFORMATION FLOW TECHNOLOGIES LLC

DISCLAIMER: Information provided herein is privileged and confidential, and not subject to disclosure, pursuant to 15 U.S.C. 638 (k)(4) and 5 U.S.C. 552. This information shall only be used or disclosed for evaluation purposes.

SBIR Company Commercialization Report

Total Investments:	Total Sales:	Total Patents:	Government Designated Phase III Funding:
$18,794,917.00	$0.00	16	$1,395,331.00

Company Information

Address:

319 1ST AVE N STE 400
MINNEAPOLIS, MN 55401-1689
United States

SBC Control ID: SBC_000000276

Company Url: https://www.sift.net/

Company POC

Title: Vice President, R&D
Full Name: Harry Funk
Phone: 6123397438 **Ext** 201
Email: hfunk@sift.net

Commercialization POC

Title: CEO
Full Name: Mark Berman
Phone: (612) 339-7438 **Ext** 210
Email: mberman@SIFT.net

Additional Company Information

% Revenue for last fiscal year from SBIR/STTR funding:	Total revenue for last fiscal year:
15.2%	$5,000,000 - $19,999,999
Year Founded:	**# Employees Currently:**
1999	42
Year first Phase I award received:	**# SBIR/STTR Phase I Awards:**
2000	56
Year first Phase II award received:	**# SBIR/STTR Phase II Awards:**
2002	25
# Employees at first Phase II award:	**Mergers and Acquisition within past 2 years:**
5	No
Spin-offs resulting from SBIR/STTR:	**IPO resulting from SBIR/STTR | Year of IPO:**
No	No | N/A
Patents resulting from SBIR/STTR | #Patents:	**List of Patents:**
Yes | 16	11755838,11468608,11372854,11256561,10963703,10528729,10217051,10217050, 10217049,10108798,9830830,9754502,9477823,9390627,9053421,8825584
Woman-Owned:	**Socially and Economically Disadvantaged:**
No	No
HUBZone-Certified:	**SBC majority-owned by multiple VCOC, HF, PE firms | By what percent (%):**
No	No | N/A

Additional Investment From

	Last Submitted Version (02-15-2021 02:31 PM)	Current Version
DoD contracts/DoD subcontracts	$11,071,697.00	$15,742,297.00
Angel Investors	$0.00	$0.00
Venture Capital	$0.00	$0.00
Self Funded	$0.00	$0.00
Private Sector	$984,770.00	$984,770.00
Other Federal Contracts/Grants	$2,014,850.00	$2,014,850.00
Other Sources	$53,000.00	$53,000.00
Additional Investment	$0.00	$0.00
Total Investment	$14,124,317.00	$18,794,917.00

Phase III Sales To

	Last Submitted Version (02-15-2021 02:31 PM)	Current Version
DoD or DoD prime contractors	$0.00	$0.00
Private Sector	$0.00	$0.00
Export Markets	$0.00	$0.00
Other Federal Agencies	$0.00	$0.00
Additional commercialization by 3rd Party Revenue	$0.00	$0.00
Other Customers	$0.00	$0.00
Additional Sales	$0.00	$0.00
Total Sales	$0.00	$0.00

Government Phase III Contracts

	Last Submitted Version (02-15-2021 02:31 PM)	Current Version
Funding Obligated	$0.00	$1,395,331.00

Commercialization Narrative

Commercialized Awards

- Listed below are the sales revenue and investment details resulting from the technology developed under these SBIR/STTR awards.

COMPEER: Community of Measured Peers — 1 of 15

Agency/Branch:	Department of Defense/Air Force	**Manufacturing related**	No | N/A
Program/Phase/Year:	SBIR/Phase II/2018	**Subsidiaries**	N/A
Topic #:	AF171-049	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	FA8750-18-C-0192	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	No		

Additional Investment From		**Phase III Sales To**	
DoD contract/subcontract:	$0.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$0.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$0.00	**Other Customers:**	$0.00
Other Sources:	$0.00		
Investment Total:	**$0.00**	**Sales Total:**	**$0.00**

REPAIRing with an OpenMIND — 2 of 15

Agency/Branch:	Department of Defense/Defense Advanced Research Projects Agency	**Manufacturing related**	No | N/A
Program/Phase/Year:	SBIR/Phase II/2022	**Subsidiaries**	N/A
Topic #:	SB162-005	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	140D0422C0046	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost	No		

avoidance?:	

Additional Investment From		Phase III Sales To	
DoD contract/subcontract:	$607,300.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$0.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$0.00	**Other Customers:**	$0.00
Other Sources:	$0.00		
Investment Total:	**$607,300.00**	**Sales Total:**	**$0.00**

COMPEER: Community of Measured Peers — 3 of 15

Agency/Branch:	Department of Defense/Air Force	**Manufacturing related**	No | N/A
Program/Phase/Year:	SBIR/Phase II/2018	**Subsidiaries**	N/A
Topic #:	AF171-049	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	FA8750-18-C-0192	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	No		

Additional Investment From		Phase III Sales To	
DoD contract/subcontract:	$124,700.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$0.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$0.00	**Other Customers:**	$0.00
Other Sources:	$0.00		
Investment Total:	**$124,700.00**	**Sales Total:**	**$0.00**

TYBALT: Transcending cYber Barriers with Automated Language Tracking — 4 of 15

Agency/Branch:	Department of Defense/Defense Advanced Research Projects Agency	**Manufacturing related**	No | N/A
Program/Phase/Year:	SBIR/Phase II/2019	**Subsidiaries**	N/A
Topic #:	SB171-009	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	FA8650-19-C-6025	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	No		

Additional Investment From		Phase III Sales To	
DoD contract/subcontract:	$984,600.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$0.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$0.00	**Other Customers:**	$0.00
Other Sources:	$0.00		
Investment Total:	**$984,600.00**	**Sales Total:**	**$0.00**

NEUTRON: Network Enforcement Using TRansctiONs — 5 of 15

Agency/Branch:	Department of Defense/Air Force	**Manufacturing related**	No | N/A
Program/Phase/Year:	STTR/Phase II/2019	**Subsidiaries**	N/A
Topic #:	AF17B-T004	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	FA8750-19-C-0082	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	No		

Additional Investment From		**Phase III Sales To**	
DoD contract/subcontract:	$642,000.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$0.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$0.00	**Other Customers:**	$0.00
Other Sources:	$0.00		
Investment Total:	**$642,000.00**	**Sales Total:**	**$0.00**

STTR Specific Information

Who initiated the collaboration?:	Small Business Concern	**Number of months taken to negotiate the Allocation of Rights agreement:**	1
Who initiated the technology?:	Research Institution	**Percentage of proceeds going to the small business:**	50%
		Percentage of proceeds going to the research institution:	50%

GEMINI: Gestalt Mixed Initiative Intelligence — 6 of 15

Agency/Branch:	Department of Defense/Air Force	**Manufacturing related**	No | N/A
Program/Phase/Year:	SBIR/Phase II/2017	**Subsidiaries**	N/A
Topic #:	AF161-045	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	FA8650-17-C-6871	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	No		

Additional Investment From		**Phase III Sales To**	
DoD contract/subcontract:	$1,615,093.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$0.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$0.00	**Other Customers:**	$0.00
Other Sources:	$0.00		
Investment Total:	**$1,615,093.00**	**Sales Total:**	**$0.00**

Government Designated Phase III Contracts

Funding Agreement / Contract #	Agency	Project Title	Year Awarded	Funding Obligated
HR00112290023	DARPA	HUGO: Humanitarian User	2021	$1,395,331.00

		Group Oversight		

Formal Synthesis and Verification Techniques for Autonomous Cyber-Physical Systems

Agency/Branch:	Department of Defense/Air Force	**Manufacturing related**	No | N/A
Program/Phase/Year:	SBIR/Phase II/2016	**Subsidiaries**	N/A
Topic #:	AF14-AT06	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	FA8650-16-C-2611	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	No		

Additional Investment From		**Phase III Sales To**	
DoD contract/subcontract:	$1,250,255.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$0.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$0.00	**Other Customers:**	$0.00
Other Sources:	$0.00		
Investment Total:	**$1,250,255.00**	**Sales Total:**	**$0.00**

Delegation in LoA3 Space

Agency/Branch:	Department of Defense/Army	**Manufacturing related**	Yes | Systems Level Manufacturing
Program/Phase/Year:	SBIR/Phase II/2008	**Subsidiaries**	N/A
Topic #:	A06-007	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	W911W6-08-C-0066	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	Yes		
a. Agency/End user:	Air Force Research Laboratory for HQ Air Force		
b. System/Program:	AFRL support contract Contract FA8650-08-D-6801, TO 39		
c. Cost Savings:	$250,000.00		
d. Cost Savings Type:	life-cycle		
e. Explanation:	A goal of the AFRL program was to have a portable, laptop-based demonstration environment for reviewing play-based delegation control concept to AF pilots in traveling focus groups. Approximately 2/3 of our Ph2 SBIR for the Army was devoted to developing		

Additional Investment From		**Phase III Sales To**	
DoD contract/subcontract:	$3,922,858.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$1,391,000.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$207,000.00	**Other Customers:**	$0.00
Other Sources:	$0.00		
Investment Total:	**$5,520,858.00**	**Sales Total:**	**$0.00**

Marshal: Maintaining Evolving Models

Agency/Branch:	National Aeronautics and Space Administration
Program/Phase/Year:	SBIR/Phase II/2015
Topic #:	H6.01
Contract/Grant #:	NNX15CA19C
Achieved a cost saving or cost avoidance?:	No
Manufacturing related	No | N/A
Subsidiaries	N/A
Other contributing SBIR/STTR awards	N/A
Used in Federal or acquisitions program?	No

Additional Investment From	
DoD contract/subcontract:	$491,537.00
Other Federal contract/grants:	$0.00
Angel Investors:	$0.00
Venture Capital:	$0.00
Self-Funded:	$0.00
Private Sector:	$0.00
Other Sources:	$0.00
Investment Total:	**$491,537.00**

Phase III Sales To	
Dod or DoD prime contractors:	$0.00
Other Federal Agencies:	$0.00
Private Sector:	$0.00
Export Market:	$0.00
3rd Party Revenue:	$0.00
Other Customers:	$0.00
Sales Total:	**$0.00**

ANSIBLE: A Network of Social Interactions for Bilateral Life Enhancement

Agency/Branch:	National Aeronautics and Space Administration
Program/Phase/Year:	SBIR/Phase II/2014
Topic #:	H12.03
Contract/Grant #:	NNX14CJ06C
Achieved a cost saving or cost avoidance?:	No
Manufacturing related	No | N/A
Subsidiaries	N/A
Other contributing SBIR/STTR awards	N/A
Used in Federal or acquisitions program?	No

Additional Investment From	
DoD contract/subcontract:	$0.00
Other Federal contract/grants:	$24,850.00
Angel Investors:	$0.00
Venture Capital:	$0.00
Self-Funded:	$0.00
Private Sector:	$0.00
Other Sources:	$0.00
Investment Total:	**$24,850.00**

Phase III Sales To	
Dod or DoD prime contractors:	$0.00
Other Federal Agencies:	$0.00
Private Sector:	$0.00
Export Market:	$0.00
3rd Party Revenue:	$0.00
Other Customers:	$0.00
Sales Total:	**$0.00**

SAGA: Sequential Art via Game Assistance

Agency/Branch:	Department of Defense/Defense Advanced Research Projects Agency
Program/Phase/Year:	SBIR/Phase II/2013
Topic #:	SB112-003
Contract/Grant #:	W31P4Q-13-C-0058
Achieved a cost saving or cost	No
Manufacturing related	No | N/A
Subsidiaries	N/A
Other contributing SBIR/STTR awards	N/A
Used in Federal or acquisitions program?	No

avoidance?:	

Additional Investment From		Phase III Sales To	
DoD contract/subcontract:	$0.00	Dod or DoD prime contractors:	$0.00
Other Federal contract/grants:	$0.00	Other Federal Agencies:	$0.00
Angel Investors:	$0.00	Private Sector:	$0.00
Venture Capital:	$0.00	Export Market:	$0.00
Self-Funded:	$0.00	3rd Party Revenue:	$0.00
Private Sector:	$0.00	Other Customers:	$0.00
Other Sources:	$0.00		
Investment Total:	**$0.00**	**Sales Total:**	**$0.00**

SAT-CIRCA: Verifiable Real-Time Autonomy for Satellites — 12 of 15

Agency/Branch:	Department of Defense/Defense Advanced Research Projects Agency	**Manufacturing related**	No | N/A
Program/Phase/Year:	SBIR/Phase II/2011	**Subsidiaries**	N/A
Topic #:	SB093-006	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	D11PC20204	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	No		

Additional Investment From		Phase III Sales To	
DoD contract/subcontract:	$1,832,054.00	Dod or DoD prime contractors:	$0.00
Other Federal contract/grants:	$0.00	Other Federal Agencies:	$0.00
Angel Investors:	$0.00	Private Sector:	$0.00
Venture Capital:	$0.00	Export Market:	$0.00
Self-Funded:	$0.00	3rd Party Revenue:	$0.00
Private Sector:	$9,600.00	Other Customers:	$0.00
Other Sources:	$0.00		
Investment Total:	**$1,841,654.00**	**Sales Total:**	**$0.00**

Extremely Low Attention Demand Information Systems (ELADIS) — 13 of 15

Agency/Branch:	Department of Defense/Defense Advanced Research Projects Agency	**Manufacturing related**	No | N/A
Program/Phase/Year:	SBIR/Phase II/2009	**Subsidiaries**	N/A
Topic #:	SB062-007	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	W31P4Q-09-C-0222	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	No		

Additional Investment From		Phase III Sales To	
DoD contract/subcontract:	$3,791,900.00	Dod or DoD prime contractors:	$0.00
Other Federal contract/grants:	$0.00	Other Federal Agencies:	$0.00
Angel Investors:	$0.00	Private Sector:	$0.00
Venture Capital:	$0.00	Export Market:	$0.00
Self-Funded:	$0.00	3rd Party Revenue:	$0.00
Private Sector:	$273,870.00	Other Customers:	$0.00
Other Sources:	$0.00		

Investment Total:	**$4,065,770.00**	**Sales Total:**	**$0.00**

Cultural Etiquette and its Impact on Directive Human Performance

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Agency/Branch:	Department of Defense/Air Force	**Manufacturing related**	Yes | Environmental/Societal Level Manufacturing
Program/Phase/Year:	SBIR/Phase II/2006	**Subsidiaries**	N/A
Topic #:	AF05-069	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	FA8650-06-C-6635	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	Yes		
a. Agency/End user:	Universities (GMU, West Point, CMU) using test beds		
b. System/Program:	ARL Decision Aiding CTA		
c. Cost Savings:	$70,000.00		
d. Cost Savings Type:	life-cycle		
e. Explanation:	Testbeds developed originally for experimentation under this SBIR were given, on 4 separate occasions, to universities to enable them to perform further, related experimentation. A very conservative estimate of 80 hours of skilled student time (=$5K) was		

Additional Investment From		**Phase III Sales To**	
DoD contract/subcontract:	$480,000.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$599,000.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$494,300.00	**Other Customers:**	$0.00
Other Sources:	$10,000.00		

Other Sources Description:
N/A

Investment Total:	**$1,583,300.00**	**Sales Total:**	**$0.00**

Cognitive Decision Aid Knowledge Acquisition Toolkit (CDAKAT)

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Agency/Branch:	Department of Defense/Army	**Manufacturing related**	Yes | Unit Process Level Manufacturing
Program/Phase/Year:	SBIR/Phase II/2002	**Subsidiaries**	N/A
Topic #:	N/A	**Other contributing SBIR/STTR awards**	N/A
Contract/Grant #:	DAAH-10-02-C-0005	**Used in Federal or acquisitions program?**	No
Achieved a cost saving or cost avoidance?:	No		

Additional Investment From		**Phase III Sales To**	
DoD contract/subcontract:	$0.00	**Dod or DoD prime contractors:**	$0.00
Other Federal contract/grants:	$0.00	**Other Federal Agencies:**	$0.00
Angel Investors:	$0.00	**Private Sector:**	$0.00
Venture Capital:	$0.00	**Export Market:**	$0.00
Self-Funded:	$0.00	**3rd Party Revenue:**	$0.00
Private Sector:	$0.00	**Other Customers:**	$0.00

Other Sources:	$43,000.00		
Other Sources Description: N/A			
Investment Total:	**$43,000.00**	**Sales Total:**	**$0.00**

CERTIFICATE OF COMPLETION

THIS CERTIFICATE IS PRESENTED TO

Scott Friedman, Smart Information Flow Technologies, d/b/a SIFT

FOR SUCCESSFULLY COMPLETING FRAUD, WASTE AND ABUSE TRAINING AND MEETING ALL REQUIREMENTS SET FORTH BY THE OFFICE OF SMALL BUSINESS PROGRAMS

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

Nov 04, 2024
COMPLETION DATE

Nov 04, 2025
EXPIRATION DATE