BY ORDER OF THE COMMANDER
AIR FORCE INTELLIGENCE SURVEILLANCE AND RECONNAISSANCE AGENCY

AIR FORCE ISR AGENCY INSTRUCTION 14-122

31 AUGUST 2010

Intelligence

AIRBORNE SYNTHETIC APERTURE RADAR (SAR) IMAGERY ARTIFACTS RESOLUTION PROCESS

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RELEASABILITY: There are no releasability restrictions on this publication.

OPR: AFISRA/A3O

Certified by: AFISRA/A3
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Pages: 61

This instruction implements Air Force Policy Directive (AFPD) 14-1, *Air Force Intelligence Planning and Operations* dated 2 April 2004. This instruction defines and establishes a formalized and standardized process for the resolution of artifacts affecting the quality and exploitability of all Air Force Airborne Synthetic Aperture Radar (SAR) imagery products collected and processed through the AF Distributed Common Ground System (DCGS) enterprise, and sets policy and guidance concerning its implementation and incorporation into existing quality assurance processes implemented for those products. It also establishes the roles and responsibilities required of all units and organizations subordinate to Air Force Intelligence, Surveillance and Reconnaissance Agency (AFISRA) that are necessary to implement, execute, and support this process. This instruction is applicable to all AFISRA units and personnel responsible for the Quality Assurance (QA) of Airborne SAR imagery products and any of its subordinate units and personnel assigned to or supporting the DCGS enterprise to include AFISRA-gained Air National Guard (ANG) and AF Reserve Command (AFRC) units. This instruction is applicable to all units and personnel at or subordinate to the 480th Intelligence, Surveillance and Reconnaissance Wing (ISRW) assigned to perform Imagery Intelligence/Geospatial Intelligence/Measurements and Signals Intelligence (IMINT/GEOINT/MASINT) exploitation of Airborne SAR imagery products obtained from the DCGS enterprise, and to the National Air and Space Intelligence Center (NASIC). Since this instruction provides only general guidance, supplemental guidance is required to be published and maintained by all units affected by this instruction IAW publishing requirements outlined in AFI 33-360, *Publications and Forms Management*. You must forward one copy of your publication to the AFISRA OPR. Refer recommended changes and questions about this publication to the Office of Primary Responsibility (OPR) using the AF Form 847, *Recommendation for Change of Publication*; route AF Forms 847 from the field through the appropriate functional's chain of command. Ensure that all records created as a result of processes prescribed in this publication are maintained in accordance with Air Force Manual (AFMAN) 33-363, *Management of Records*, and disposed of in accordance with Air Force Records Information Management System (AFRIMS) Records Disposition Schedule (RDS) located at **https://www.my.af.mil/gcss-af61a/afrims/afrims/**. Contact supporting records managers as requi

ed.

1. Purpose. The purpose of this instruction is to define and establish a process for the resolution of artifacts and anomalies affecting the quality and exploitability of all Air Force Airborne SAR imagery products collected and processed through the AF DCGS enterprise, and to set policy and guidance concerning its implementation and incorporation into existing image quality assurance and exploitation processes implemented for those products. For the purposes of this instruction, this process shall be referred to as the Airborne SAR Artifacts Resolution Process.

2. Background. The exploitability of any IMINT image product is generally governed by its overall Image Quality (IQ). The IQ associated with Airborne SAR IMINT/GEOINT/MASINT products is generally governed by their artifact content. The regular and repeated appearance of artifacts within current AF Airborne SAR imagery products hampers or prohibits Image Analysts from performing exploitation by degrading and/or masking the intelligence content available within those products. As a result, the presence of artifacts within SAR imagery products impedes the satisfaction of the intelligence requirements on which their exploitation depends and hinders overall mission accomplishment. Current efforts within the Air Force focus on attempting to control the IQ associated with Airborne SAR imagery products strictly from a sensor perspective—ensuring the health, status, and performance of the sensor architecture. Such efforts manage Airborne SAR IQ by taking a classic sample-and-evaluate Quality Assurance (QA) approach—sampling image products on a time interval basis, analyzing and assigning qualitative and quantitative metrics, and utilizing those metrics to assess long-term trends in the degradation of sensor architecture performance as well as evaluate the performance of maintenance processes executed on the sensor architecture in the field. While this approach may be suitable for managing IQ from the sensor architecture perspective, it does not address degradations in IQ resulting from sources or causes other than the sensor architecture performance, nor is it effective for identifying issues in sensor architecture performance that are of an intermittent or causal nature that do not happen to get sampled with that QA approach. Artifacts affecting SAR IQ can also be present due to numerous other causes, but in particular are due to irregularities in the motion or attitude of the airborne platform during collection, use of extreme or out-of-tolerance collection geometries, and occurrences of intentional or unintentional EMI events in the environment during collection. However, it is possible for a number of these particular artifacts to be mitigated, compensated, or eliminated through corrective or mitigating action, provided that these artifacts can be identified and attributed to their particular causality. This can only be accomplished through a process of artifact resolution.

3. Objectives. The overall objective of the Airborne SAR Process is NOT to attempt to resolve all the artifacts that can possibly occur within AF Airborne SAR imagery products, but to improve the overall IQ and resultant exploitability of SAR imagery products through reduction of only those artifacts that are able to be resolved to causalities that are within Air Force ability to eliminate, compensate, or mitigate. To this end, the specific objectives of this process are to identify those artifacts that can be attributed to causalities in which specific courses of action may be taken to: (1) avoid the causal conditions associated with, (2) initiate a process of mitigation that results in compensation for, or (3) initiate a process of correction that results in elimination of their occurrence from future SAR imagery product collections. As such, the specific artifact causalities of interest to this process are those due to: (1) deficiencies in sensor collection processes, (2) effects of intentional or unintentional EMI, or (3) those intermittent or selectively causal anomalies in sensor architecture, to include anomalies that are detected through current existing sensor architecture sample-and-evaluate QA processes and are deemed necessary to report and investigate.

4. Expected Results. As a result of implementation of this instruction, it is expected that incorporation of this Airborne SAR Process into existing image quality assurance and exploitation processes for Air Force Airborne SAR imagery products will:

4.1. Facilitate a comprehensive Quality Management approach to controlling image quality that complements and expands constrained areas of the current sensor architecture Quality Assurance approaches.

4.2. Provide a vehicle for incorporating advanced exploitation techniques to mitigate artifact-affected image products (when possible) to enable product exploitation without re-tasking and re-collection.

4.3. Use advanced exploitation techniques to develop advanced signatures of artifacts characteristic of prior resolved EMI and sensor architecture anomalies that will enable image analysts to readily identify and report occurrence of such events for immediate action.

4.4. Facilitate identification and resolution of artifacts attributable to specific sensor architecture operational limitations not evident to sensor collection planners that cause or contribute to artifact occurrence so that such limitations and operational practices may be avoided, thus reducing artifact occurrence.

4.5. Enable identification and resolution of artifacts due to causalities resulting from unintentional practices in existing TCPED and/or CM processes and the subsequent correction of those practices.

4.6. Augment sensor anomaly resolution processes by performing causality analyses to eliminate likelihood of EMI and other causalities which always have to be done in order to rule out external causes.

4.7. Provide a conduit for the identification and migration of tools and techniques developed and used in the NTM community to facilitate better product exploitation and artifact mitigation from affected products.

4.8. Enable identification of intermittent and causal sensor architecture anomalies that are not reliably identified by current sensor architecture quality assurance processes.

4.9. Incorporate the collection of detailed metrics that enable analysis and evaluation of the impacts that integration of this process has on overall image quality and reduction of artifacts in products.

4.10. The enclosed attachments encompassing the Airborne SAR Artifact Recognition and Reporting procedures and processes are intended to provide the minimum standards and form the baselines for unit specific operating instructions and checklists. They may be refined and modified based on real-world mission execution results to improve process efficiency and mission effectiveness.

5. Responsibilities.

5.1. AFISRA/A3 will:

5.1.1. Maintain overall responsibility for AFISRA subordinate unit implementation of this instruction by providing policy and guidance.

5.1.2. Appoint a lead office (OPR) for oversight and management of the implementation of this instruction (AFISRA/A3O).

5.1.3. Approve instruction revisions and updates as required.

5.2. AFISRA/A3O will:

5.2.1. Provide oversight and guidance for integration of the Airborne SAR Artifacts Resolution Process into existing image quality assurance processes at the Wing/Center/Group/unit level.

5.2.2. Coordinate participation by all associated image quality assurance process entities at the Wing/Center/Group/unit level in any forum to create, update, or amend HQ USAF operational or intelligence policy or doctrine as a result of executing the processes of this instruction; such as Air Force Instructions or Tactics, Techniques and Procedures.

5.2.3. Review Wing/Center supplemental publications to verify compliance with this instruction. Publications should be received no later than 30 days after date of publication or revision.

5.2.4. Initiate, coordinate, and conduct headquarters staff actions to organize, man, and train forces as necessary to execute the processes of this instruction.

5.2.5. Coordinate on Memorandums of Agreement, Memorandums of Understanding, and other support agreements between all associated image quality assurance process entities at the Wing/Center/Group/unit level and the external organizations necessary to execute the processes of this instruction.

5.2.6. Review this instruction annually and revise/update as required.

5.3. 480 ISRW will:

5.3.1. Establish a Wing OPR to work with the AFISRA OPR. Provide name and contact information to the AFISRA OPR and update as needed.

5.3.2. Apprise the AFISRA OPR of all issues requiring AFISRA attention. The AFISRA OPR is the AFISRA entry point for all issues pertaining to the implementation and execution of this instruction to ensure that all issues are addressed and resolved.

5.3.3. Identify, develop, and consolidate requirements for manpower, systems, facilities, and resources to implement and execute the processes of this instruction and forward to the AFISRA OPR.

5.3.4. Publish and maintain supplemental policy and guidance for the implementation and execution of this instruction for subordinate units consistent with AFISRA policy and guidance. Forward a copy of all supplemental publications to the AFISRA OPR no later than 30 days from date of publication and/or revision.

5.3.5. Review Wing supplemental publications policy and guidance annually, and revise/update as required.

5.3.6. Ensure subordinate units publish and maintain local supplemental publications as required for implementation and execution of this instruction. Forward a copy of all local publications to the AFISRA OPR no later than 30 days from date of publication and/or revision.

5.3.7. Review subordinate unit local publications annually and direct revisions as required.

5.3.8. Develop and coordinate support agreements with relevant associated image quality assurance process entities at the Wing, Group and Unit level, and the Direct Liaison Authorized (DIRLAUTH) to external organizations necessary to execute the processes of this instruction.

5.3.9. Identify, develop, and consolidate requirements for training necessary to implement and execute this instruction and forward to the AFISRA OPR.

5.3.10. Develop training specific to mission support requirements and ensure required personnel are fully trained to execute the processes of this instruction.

5.3.11. Implement a training program to ensure forces are capable of executing the processes of this instruction.

5.3.12. Monitor the effectiveness of the 480 ISRW quality assurance processes executed from this instruction and provide feedback to the AFISRA/A3O.

5.3.13. Review this instruction annually and recommend revisions as required.

5.4. NASIC will:

5.4.1. Establish a Center OPR to work with the AFISRA OPR. Provide name and contact information to the AFISRA OPR and update as needed.

5.4.2. Apprise the AFISRA OPR of all issues requiring AFISRA attention. The AFISRA OPR is the AFISRA entry point for all issues pertaining to the implementation and execution of this instruction to ensure that all issues are addressed and resolved.

5.4.3. Publish and maintain supplemental policy and guidance, for the implementation and execution of this instruction for subordinate units consistent with AFISRA policy and guidance. Forward a copy of all supplemental publications to the AFISRA OPR no later than 30 days from date of publication and/or revision.

5.4.4. Develop and coordinate agreements for analytical support with the Direct Liaison Authorized (DIRLAUTH) to external organizations necessary to execute the processes of this instruction.

5.4.5. Monitor the effectiveness of the NASIC quality assurance processes executed from this instruction and provide feedback to the AFISRA/A3O.

5.4.6. Provide analytical support to any image quality assurance process entities' executing the processes of this instruction in regards to identification and analysis of artifacts within Airborne SAR imagery products.

5.4.7. Review this instruction annually and recommend revisions as required.

5.4.8. Identify, develop, and consolidate requirements for manpower, systems, facilities, and resources to implement and execute the processes of this instruction and forward to the AFISRA OPR.

6. Airborne SAR Artifacts Resolution Process.

6.1. Introduction. This section begins with a background statement discussing the current QA processes that are presently in place for Airborne SAR imagery sensors and why these QA processes are inadequate toward improving the overall IQ of Airborne SAR imagery products. Following this, a brief discussion is presented to describe the phenomenology associated with artifacts within SAR imagery products. This discussion defines terminology and identifies some key characteristics of artifacts and the associated causes of artifacts that can be used as a basis for an artifact resolution process. Following this, the Airborne SAR Process is presented in detail.

6.2. Background. The exploitability of any IMINT image product is generally governed by its overall IQ. The IQ associated with SAR imagery products is generally governed by their artifact content. The regular and repeated appearance of artifacts within current AF Airborne SAR imagery products represents a significant concern to both product IQ and sensor architecture performance. Current efforts employed to control the IQ associated with Airborne SAR imagery products are only being performed from a sensor architecture perspective—ensuring the health, status, and performance of the sensor architecture. Such efforts manage SAR IQ by utilizing a classic sample-and-evaluate Quality Assurance (QA) approach—sampling image products on a time interval basis, analyzing and assigning qualitative and quantitative metrics, and utilizing those metrics to primarily determine long-term trends in the degradation of sensor architecture performance as well as evaluate the performance of maintenance processes executed on the sensor architecture in the field. This approach is used primarily because the quality to which the sensor architecture produces images is a key indicator of sensor architecture performance and is generally the first indication of sensor architecture anomaly. This approach is also reflective of the fact that IQ first and foremost depends on a sensor architecture that is fully functional and operational. However, much of the focus of this QA approach is on detecting anomalous behavior within the sensor architecture as a means to maintain the overall IQ performance. While this approach may be suitable for managing IQ only from the sensor architecture perspective, it does not adequately address degradations in IQ resulting from sources or causes other than the sensor architecture. What is necessary for comprehensive management and control of IQ is an approach that focuses on IQ factors beyond the limits of sensor architecture performance—one that focuses on IQ factors from all causalities and one that is not limited by the narrow sampling constraints of the classic sample-and-evaluate QA approach. This necessitates an approach that seeks to manage and control Airborne SAR IQ from an artifacts perspective.

6.3. Artifact Phenomenology. Although this concept is not defined in technical literature, artifacts have their own distinct phenomena in terms of the characteristics of their visual appearance in SAR imagery products as well as in terms of their causality. Unfortunately, no uniform or standardized terminology exists to describe the phenomena associated with artifacts. For the purposes of this instruction, the following sections attempt to define some terminology and concepts for artifacts in particular, two important concepts: artifact signature and artifact causality. Their relevance will become apparent when these concepts are used in the context of artifact resolution.

6.3.1. Artifact Signature. In general, the term artifact is used to describe a broad scope of visual effects in SAR imagery that do not represent the true target scene content. These effects are categorized by their appearance and/or cause. The appearance of the artifact may be entities that are located discretely within the image such as points, lines or shapes, or the artifact appearance can be an overall visual affect such as defocus or lack of contrast. In terms of range of effect, an artifact may have uniform effect or repeated occurrence over the entire image or only over a portion of the image with a definite or distinctive boundary between its affected and non-affected portions. It also may only occur as a singular entity located anywhere within the image. Artifact signature refers to the visually observable characteristics and attributes that an artifact exhibits that serve to distinguish it from other artifacts within a SAR imagery product. In the case of non-unique artifact signatures, an artifact signature may become mistakenly attributed to only one of the known possible causes, may be actually attributable to a cause which has yet to be known or understood, or may not be resolvable at all from all the known possible causes with the information available. A prime example of this is artifact signatures produced from EMI events being indistinguishable from potential sensor architecture anomalies. Given the existence of these ambiguities, it is clear that artifact signatures cannot always be attributed to their associated cause solely from their visual characteristics observable from a detected SAR imagery product alone. However, artifact signatures may be characterized by more than the properties observed from the viewable images of both detected and complex SAR imagery products. In exploiting radar imagery, one must be able to distinguish between artifacts and phenomenology. Radar phenomenology is important to note, because they are not problems with the system, just effects that are intrinsic to radar systems. Phenomenology content examples would include glint, layover, motion blur (movers), or wind/wave smear.

6.3.1.1. Artifact Static Signature. All discussion to this point regarding artifact signatures has been limited to signatures as observable in the viewable images of both detected and complex SAR imagery products. In general, the viewable image of a SAR imagery product presents only a static representation of its associated contents. As such, a given artifact signature observed from the viewable image of a SAR imagery product only presents the static representation of that artifact signature. For the purposes of this instruction, this static representation of artifact signature, as observed from the contents of a viewable image of a detected or complex SAR imaging product, shall be referred to as the Artifact Static Signature.

6.3.1.2. Artifact Dynamic Signature. In reality, all of the contents of the viewable image of a SAR imaging product, both its target and artifacts content, actually represent the culmination of all the radar imaging data collected during a SAR imaging collection scenario. Given that a SAR image collection actually occurs over an extended time period as the SAR platform flies through its collection aperture, the final SAR image product can be impacted by effects that have a time-varying or dynamic nature. As such, some artifact signatures may have a dynamic character in affected SAR imagery products. This dynamic character is an important characteristic of the artifact that can potentially be used as an identifying or discriminating characteristic. However, this dynamic character is generally masked from view because the viewable image of a SAR imagery product only presents the static representation of that artifact signature—the Artifact Static Signature. The dynamic representation of artifact signatures, if it exists, can be viewed from a SAR Dynamic Imaging (DI) product. Viewing of the dynamic representation of an artifact signature, however, may be hampered by the fact that DI products can only be generated from complex SAR product sources—detected SAR imagery products are not capable of being used to generate DI products. As such, observing this dynamic character of an artifact signature from detected SAR imagery products is not possible. The lack of the ability to even determine whether or not an artifact signature has a dynamic character can be a severely limiting factor in artifact resolution. For the purposes of this instruction, the dynamic representation of an artifact signature (if it exists), as observed from a SAR Dynamic Imaging (DI) product, shall be generally referred to as the Artifact Dynamic Signature.

6.3.1.3. Artifact Frequency-Phase Domain Signatures. In addition to the dynamic characteristics that an artifact signature may exhibit, frequency and phase domain characteristics may also appear in artifact signatures. In other words, artifact signatures may have frequency and phase domain representations which are not detectable from the viewable image of a SAR imagery product. This representation can only be viewed with the aid of an image analysis tool, such as CASE Executive. Furthermore, the frequency and phase domain representations of a SAR image product can only be generated from complex SAR imagery product sources (i.e., detected SAR imagery products are not capable of being used to view the frequency and phase domain representations of a SAR image). As such, artifact frequency and phase domain signature characterization from detected SAR imagery products is not possible. The lack of the ability to even determine whether or not an artifact signature has a frequency and phase domain characteristic can also be a severely limiting factor in artifact resolution. For the purposes of this instruction, the frequency and phase domain representations of an artifact signature, as observed from the Frequency Domain Magnitude Component and Frequency Domain Phase Component image representations of the SAR imagery product, shall be referred to as the Artifact Frequency and Phase Signatures, respectively.

6.3.2. Artifact Causality. Artifact causality refers to the one or more causal factors involved in the appearance of an artifact within the final image product. Artifacts within SAR imagery products are inherent to SAR imagery due to the utilization of radar as a basis for image collection. Artifacts occur within SAR imagery products due to numerous interrelated factors both internal and external to the sensor platform, which include but are not limited to: naturally occurring topography within the imaged scene, presence of severe weather and/or atmospheric effects, presence of motion within and in the vicinity of the imaged scene, irregularities in the motion and/or attitude of the airborne platform during the collection process, collection geometries and constraints, problems or limitations in the algorithms within the image formation processes used to produce the final image product, presence of electromagnetic interference (EMI) within the vicinity of the image target or airborne platform, and/or anomalies experienced in the imaging sensor architecture (i.e., hardware and software). This may be further complicated by the fact that two or more of any of these factors may be operating simultaneously producing multiple and convoluted effects. The inherent complexity associated with SAR imagery makes the process of attributing an observed artifact to a definitive cause an extremely difficult task—one that sometimes cannot be performed without detailed radar engineering and image science analysis, and in some instances, experimental verification. Similar to that of artifact signatures, artifact causalities also have characteristics in terms of their ability to specifically effect or limit certain static and dynamic aspects of the artifact signatures they produce in imagery products. Although these discriminating effects cannot be used for causality identification, they can be used in many instances to rule out or discriminate between specific causalities of an artifact signature based on the probability of whether or not the artifact signature exhibits these characterizing effects. As such, these effects can be used as part of a process of elimination, and together with other information, may serve to rule out enough of the potential causalities to provide a sufficient basis for a specific artifact causality attribution.

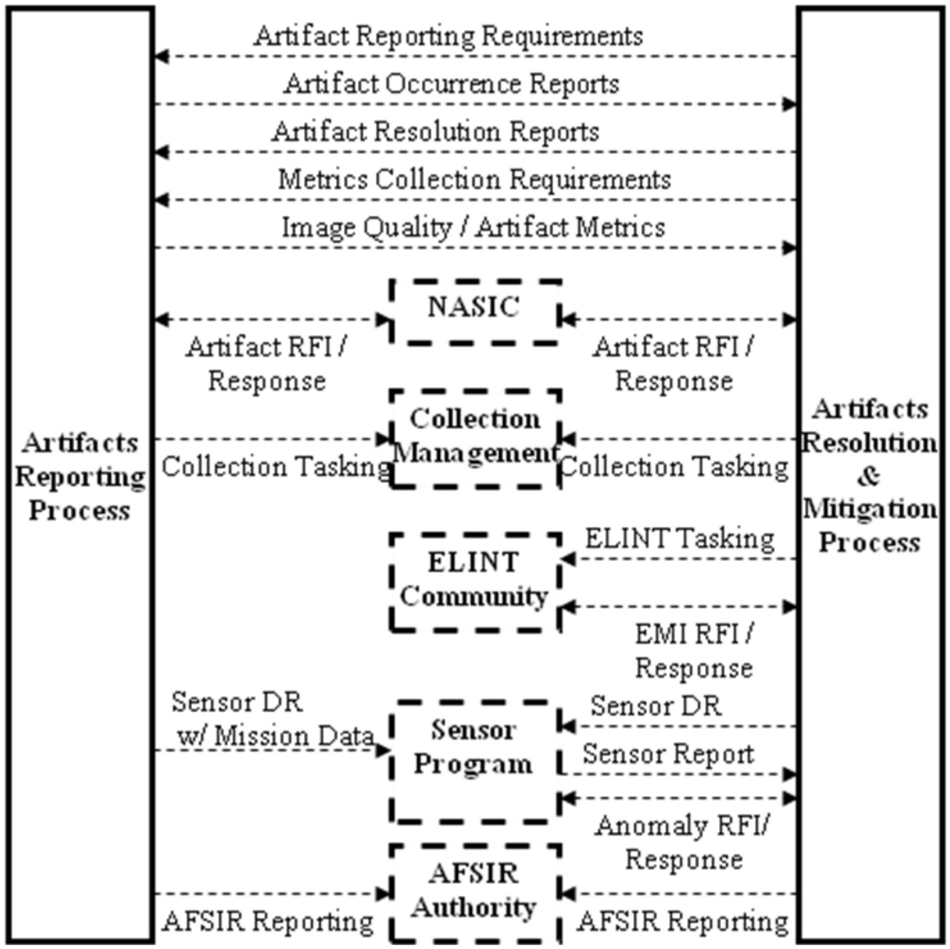
6.3.3. Non-Image Derived Information. At this point, it should be clear that causality cannot always be attributed to an artifact or phenomenology solely on the basis of the characteristics and attributes of the signature alone. As such, additional information is required to be able to attribute an artifact signature to its particular causality. As learned from the discussion of artifact causality, some artifact causalities may also be characterized by the circumstances associated with their occurrence or the lack of any circumstances attributable to their occurrence. It is these circumstances of occurrence that form the basis of the additional information that needs to be collected in association with an occurrence of an artifact signature in a specifically collected image product. In general, this information can be characterized into the following categories: image collection data, target history data, collection mission data, and sensor configuration data.

6.3.4. Artifact Resolution. Artifact resolution is defined, for the purposes of this instruction, as the analytical process undertaken to attribute an artifact to a particular causality. As learned from the discussions concerning artifact signatures and artifact causality, the ambiguities that exist between and amongst signatures and their potential causalities impede the attribution of certain artifacts that may appear in SAR imagery products to their true causality, in particular to the causalities that are of primary concern in this instruction—collection process factors, intentional or unintentional EMI, and sensor architecture anomaly. In cases where an artifact signature is distinctive amongst other artifact signatures AND unique to one and only one causality, attribution to that causality is straightforward and done with little risk of error from the detected SAR imagery product alone. However, in light of the ambiguities possible amongst artifact signatures, it is clear that using an artifact signature observed from detected SAR imagery products cannot always and reliably be the sole basis for identification and attribution to its causality—other methods must be used to determine artifact causality. One such method is to utilize the characteristics and attributes of artifact signatures and the discriminating characteristics of artifact causalities, in conjunction with the use of non-image derived information (e.g., collection meta-data) and deductive reasoning to perform a process of elimination of potential artifact causalities progressively toward a path of complete resolution. It is this process that is to be employed for artifact resolution in this instruction.

6.4. Airborne SAR Process. The Airborne SAR Process is a comprehensive process for the identification, characterization, resolution, and mitigation of artifacts in AF Airborne SAR imagery products. Given that this process is to be incorporated into existing image quality assurance and exploitation processes implemented for those products, this necessitates the overall Airborne SAR Process to be decomposed into distinctive quality assurance and exploitation components as well. As such, the Airborne SAR Process is comprised of two component processes: an Artifacts Reporting (AR) Process, to be incorporated into existing image product exploitation processes, and an Artifacts Resolution & Mitigation Process (AR&M), to be incorporated into existing image quality assurance processes. The primary objective of the Airborne SAR Artifacts Reporting Process is to identify artifacts from SAR imagery products requiring further resolution that cannot be performed by image analysts without affecting production requirements associated with current imagery exploitation processes. Such artifacts are reported to image quality assurance personnel engaged in the Airborne SAR AR&M Process. The primary objective of the Airborne SAR AR&M Process is to obtain reports of artifacts from image exploitation personnel engaged in the AR Process and take actions as required to resolve the artifact to its associated causality and, if possible to either mitigate or correct its occurrence in future product collections.

6.4.1. Airborne SAR Process Internal and External Interfaces. The relationship between the Artifacts Reporting Process and the Artifacts Resolution & Mitigation Process is primarily one of information flow, as depicted in Figure 6.1. As well as information flow between these component processes, the figure also depicts the information interfaces between the component processes and external entities outside the overall Airborne SAR Process.

Figure 6.1. Airborne SAR Process Internal and External Interfaces.



6.4.1.1. Airborne SAR Process Internal Interfaces. The following internal information interfaces within the Airborne SAR Process are defined:

6.4.1.1.1. Artifact Reporting Requirements. Artifact Reporting Requirements establish requirements for the repeated and continued reporting of both currently unresolved and prior resolved artifacts from the AR Process to the AR&M Process. In general, Artifact Reporting Requirements reflect the relative priorities and reporting needs of artifact resolution activities in the AR&M Process.

6.4.1.1.2. Artifact Occurrence Reports. Artifact Occurrence Reports are the means by which artifacts are reported from the AR Process to the AR&M Process. Artifact Occurrence Reports are generated based on the Artifact Reporting Requirements established by the AR&M Process. In general, Artifact Occurrence Reports will be required to be generated as a result of first time observance of all newly unresolved artifacts identified in the AR Process. Subsequent reporting of repeated occurrences of prior observed unresolved artifacts is then governed by Artifact Reporting Requirements from the AR&M Process based on whether or not the unresolved artifact is in the process of resolution or is determined to be ignored as a result of priorities or other factors. Artifact Occurrence Reports document all of the characteristics of the artifact being reported, to include but not limited to: a general description of the artifact, the imagery product in which the artifact was observed (annotated if necessary), any supporting DI image products identifying potential artifact dynamic signature, any supporting Frequency/Phase Domain images identifying potential artifact frequency and phase signatures, image collection parameters, rationale for reporting the artifact (if first time observance), and any other supporting information used to identify and characterize the artifact.

6.4.1.1.3. Artifact Resolution Reports. Artifact Resolution Reports are the means by which the results of artifact resolution activities are reported from the AR&M Process to the AR Process. Artifact Resolution Reports document all the information relevant to the AR Process for the resolution of the artifact, or for an artifact that is in the process of resolution. Artifact Resolution Reports may take the form of either final reports or interim reports. Final Reports identify artifacts that have completed the resolution process. Conversely, Interim Reports are used to document artifacts that are in the process of resolution, and in some cases, this process may take a long duration of time as many factors are examined as possible causes of the anomaly. Interim Reports also are used to support the need to communicate artifact resolution progress and other relevant information to the AR &M Process, and facilitates the initiation of performing increasingly refined artifact signature identification and verification, performing specific local artifact resolution, and supporting requirements for further reporting and/or potential artifact exploitation mitigation techniques. Artifact Resolution Reports may also be generated for artifacts which are unresolved and are expected to remain unresolved in the foreseeable future, as well as fully resolved artifacts, in order to communicate the same relevant information as conveyed by interim reports.

6.4.1.1.4. Metrics Collection Requirements. Metrics Collection Requirements establish requirements for the repeated and continued recording of both image quality and artifact occurrence metrics collected from the AR Process and reported to the AR&M Process. In general, Metrics Collection Requirements support the ability to perform unresolved artifact impact assessment and to assign or modify the relative priorities to be assigned to artifact resolution activities in the AR&M Process. They also support the ability to evaluate the overall effectiveness of the Airborne SAR Process in affecting SAR image product quality.

6.4.1.1.5. Image Quality / Artifact Metrics. Image Quality/Artifact Metrics are collected by the AR Process and reported to the AR&M Process to evaluate the overall effectiveness of the Airborne SAR Process in affecting SAR image product quality. They are also used as a basis for the assessment of the impacts that artifact occurrences have on image exploitation processes as well as a basis for the assignment or modification of the relative priorities to be assigned to artifact resolution activities in the AR&M Process.

6.4.1.2. Airborne SAR Process External Interfaces. The following external information interfaces are defined:

6.4.1.2.1. Collection Tasking. Collection Tasking refers to specific IMINT/GEOINT/MASINT tasking for Airborne SAR imagery sensors. Collection Tasking takes different forms depending on whether it is from the Airborne SAR AR Process or the Airborne SAR AR&M Process. When it is from the Airborne SAR AR Process, it takes the form of tasking to re-collect a SAR imagery product that cannot satisfy exploitation requirements. This tasking may be modified from the tasking of the original collection so as to mitigate artifact occurrence in subsequent collection. When it is from the Airborne SAR AR&M Process, it may take the form of either tasking to generate imagery products with repeated artifact occurrence in order to verify a particular artifact causality or as part of a coordinated collection plan in conjunction with ELINT Tasking in order to confirm EMI causality or disprove sensor anomaly causality associated with a particular artifact.

6.4.1.2.2. ELINT Tasking. ELINT Tasking is created from the Airborne SAR AR&M Process. ELINT Tasking is generally used as part of a coordinated collection plan in conjunction with specific Collection Tasking (IMINT/GEOINT/MASINT) for Airborne SAR imagery sensors in order to confirm EMI causality or disprove sensor anomaly causality associated with a particular artifact.

6.4.1.2.3. Artifact Request for Information (RFI) / Response. The Artifact RFI/Response interface refers to the specific requesting and obtaining artifact identification and characterization support from NASIC. Support from NASIC Subject Matter Experts may be used in both Airborne SAR AR and AR&M Processes.

6.4.1.2.4. EMI RFI / Response. The EMI RFI/Response interface refers to the specific requesting and obtaining EMI verification support from the ELINT Community.

6.4.1.2.5. Air Force Spectrum Interference Resolution (AFSIR) Reporting. AFSIR Reporting is a general term for the reporting of EMI events in accordance with the reporting procedures of AFI 10-707, *Spectrum Interference Resolution Program*. The EMI Report specified by AFI 10-707 is used for this purpose.

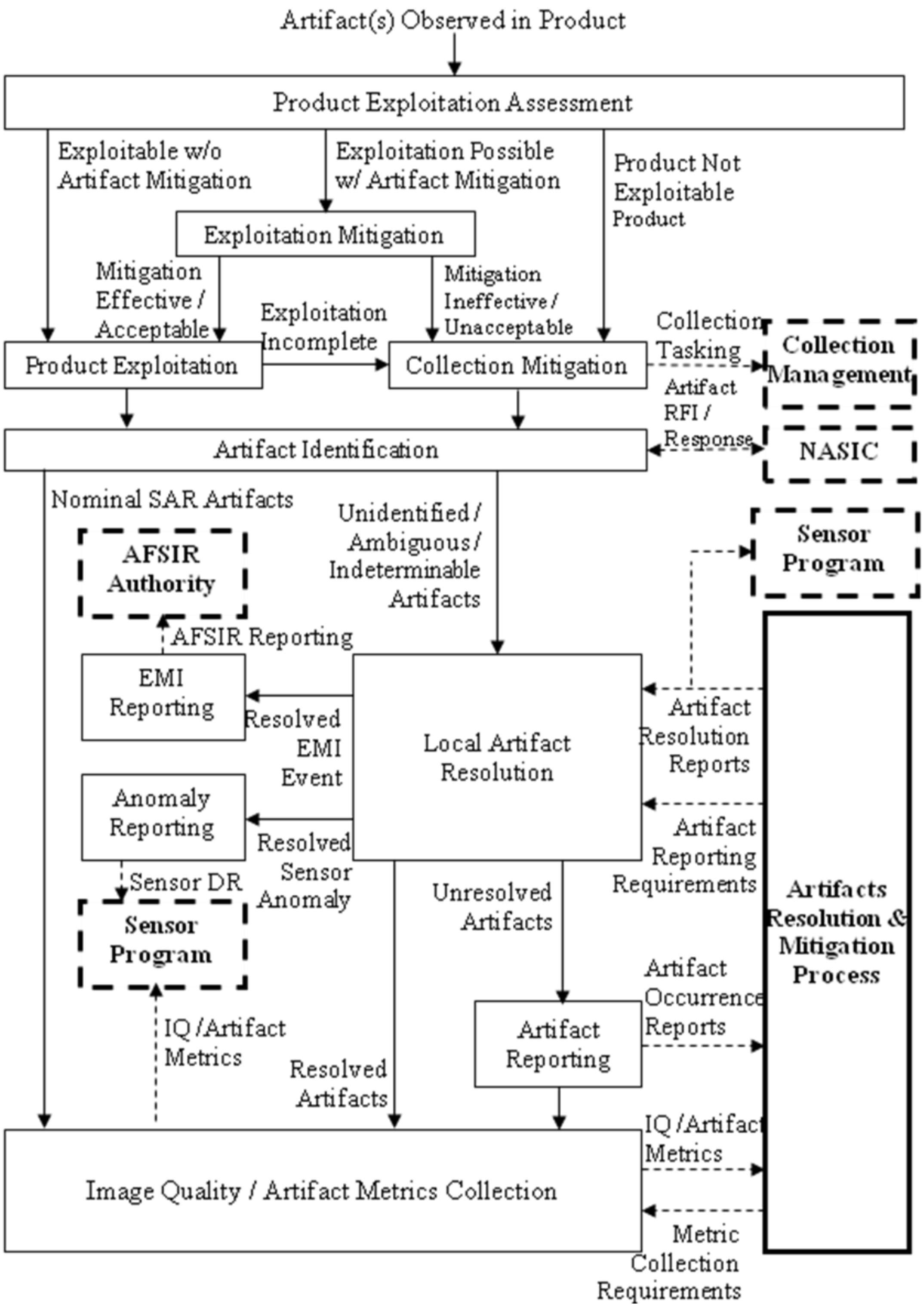
6.4.1.2.6. Anomaly Request for Information (RFI) / Response. The Anomaly RFI/Response interface refers to the specific requesting and receiving of anomaly verification support from the Sensor Program for the particular sensor involved. This interface should allow for the transfer of anomaly metrics, and any other pertinent requirements or data requests from the Sensor/Sustainment Program to aid in troubleshooting and/or investigation efforts of artifact/anomaly events.

6.4.1.2.7. Sensor Deficiency Report (DR). A DR is the general mechanism for the reporting of sensor anomalies in accordance with the reporting procedures of the Sensor Program for the particular sensor involved. Sensor Deficiency Reports may be generated from either of the Airborne SAR AR or AR&M Processes.

6.4.1.2.8. Sensor Report. Reporting generated from the sustainment support out of AFMC/WR – Senior Year Quality Assurance Program (SYQAP) focusing on ASARS-2A Image Quality within the DCGS enterprise. The Sensor Reporting effort, the AR, and the AR&M processes should have the ability to feed each other in support of information and data flow for image quality/artifact metrics collection, along with artifact/anomaly resolution or mitigation.

6.4.2. Airborne SAR Artifacts Reporting Process. The Airborne SAR Artifacts Reporting Process is shown in Figure 6.2. The overall objective of this process is to identify SAR imagery artifacts requiring further resolution, attempting to resolve them through locally available information and resources, and reporting those locally unresolveable artifacts to personnel implementing the Airborne SAR Artifacts Resolution & Mitigation Process. The process begins with Airborne SAR imagery products that are affected by artifact content—for those SAR imagery products that have no artifact content, normal exploitation processes will be performed.

Figure 6.2. Airborne SAR Artifacts Reporting Process.



6.4.2.1. Product Exploitation Assessment. The objective of Product Exploitation Assessment is to assess the overall exploitability of the artifact-affected SAR imagery product with respect to the Exploitation Requirements (ERs) and Collection Requirement (CR) Essential Element of Information (EEI) set for the collected product. If the product can be exploited as is with its artifact content present—artifacts that do not interfere with the specific exploitation requirements associated with the collected product, it is referred directly to Product Exploitation. However, if the artifact content does interfere with product exploitation but appears to be potentially exploitable if the artifact content were able to be mitigated in some fashion, the product is referred to Exploitation Mitigation. If the imagery product is so marred by artifact content that it is not exploitable at all or cannot be improved with Artifact Mitigation, the product is directly referred to Collection Mitigation.

6.4.2.2. Exploitation Mitigation. The objective of Exploitation Mitigation is to attempt to use locally available tools and/or advanced exploitation techniques to mitigate the artifact content affecting the imagery product specific to its associated exploitation requirements. However, such tools and techniques are generally limited to certain types of artifact content as well as the specific type of SAR imagery product involved—detected or complex. In the case of a detected imagery product, mitigation is limited to using tools (if available) that manipulate the final detected image directly, affecting the overall content of the image product, both artifact and intelligence content. When such tools are able to be utilized, the resulting mitigated product must be further assessed to determine the severity to which the intelligence content of the product was affected, and whether or not the effects degraded the associated intelligence content sufficiently to impede satisfaction of exploitation requirements. In the case of a complex imagery product, the imagery analyst may have access to both tools and advanced exploitation techniques depending on the type of artifact content present. If such tools or techniques can be applied, the resultant artifact mitigated product must also be assessed as to whether or not it was effective in mitigating the specific artifact content that was interfering with exploitation. In either case, if the artifact mitigation was effective in mitigating the artifact content affecting exploitation and was able to provide a resultant product that preserves the intelligence content sufficiently to meet exploitation requirements, the resultant mitigated product is referred to Product Exploitation. However, if the artifact mitigation was not effective at all or was not able to provide a resultant product acceptable for exploitation, Collection Mitigation is required to be performed.

6.4.2.3. Product Exploitation. The objective of Product Exploitation is to perform exploitation of either the original image product with its artifact content present or with the mitigated product(s) obtained from Exploitation Mitigation. If exploitation is performed successfully and completely, the product(s) is (are) referred to Artifact Identification for the handling of its residual artifact content—artifacts that did not affect exploitation of the original product. However, if the original or mitigated imagery products are still unable to be exploited to the extent necessary to fully meet exploitation requirements, Collection Mitigation will also still be required.

6.4.2.4. Collection Mitigation. The objective of Collection Mitigation is to determine whether or not modification of specific aspects of the original collection tasking is required to be changed in order to mitigate the artifact content from subsequent collection. If the artifact content within the affected imagery product is assessed as most likely a result of unfortunate or coincidental circumstances, the product may be referred for re-collection with no modification of collection parameters. If, however, the artifact content in the affected imagery product is assessed to be due to collection geometry issues, then the image product must be analyzed to determine the appropriate or optimal imaging azimuth and/or collection geometry that should be used in subsequent collection to eliminate or mitigate artifact occurrence. Other artifact causalities may be attributed to the sensor architecture operating at or beyond its capabilities or limitations for acceptable and reliable image quality, which could be a direct result of deficiencies in Air Force TPED, Collection Management, and/or sensor operational collection processes. Collection Mitigation requires direct coordination with the Collection Manager for the particular sensor involved to mitigate collection tasking parameters.

6.4.2.5. Artifact Identification. The objective of Artifact Identification is to identify all artifact content within affected imagery products as required for the Local Artifact Resolution and Metric Collection process elements. Artifact identification is to be performed to the level that is required according to the requirements established for artifacts metrics collection from the AR&M Process. To facilitate this, image analysts will utilize local information resources, exploitation techniques, and/or the support of NASIC Subject Matter Experts to discriminate between and identify the specific artifact contents within the affected product. Support from NASIC Subject Matter Experts is accomplished through the exchange of Artifact RFI / Response Messages.

6.4.2.6. Local Artifact Resolution. The objective of Local Artifact Resolution within this AR Process is to perform artifact resolution at the lowest possible level within the constraints and limitations of personnel performing image exploitation processes. The purpose of artifact resolution in this context is NOT to perform artifact causality analysis to resolve artifacts to their associated causality (as performed in the AR&M Process), but to use the results of the AR&M Process, in the form of Artifact Resolution Reports, as a basis for the identification and reporting of repeated or continuing occurrences of artifacts that either have been resolved prior to or are in the process of resolution. Artifact Resolution Reports will also be used as the basis for distinguishing new artifacts that have not been observed during previous observations of resolved or unresolved artifacts. The chief function of Local Artifact Resolution in the AR Process is to distinguish between resolved and unresolved artifacts in imagery products to be used as a basis for the generation of Artifact Occurrence Reports in Artifact Reporting and for the collection of artifact metrics in Metrics Collection. Its function is also to use the Artifact Resolution Reports of artifacts resolved to prior EMI events and sensor anomalies as a basis for their identification and direct and immediate reporting of occurrences of such events and anomalies solely from the observance of their distinctive artifact signatures in current imagery product.

6.4.2.7. Artifact Reporting. The objective of Artifact Reporting is to generate Artifact Occurrence Reports according to the Artifact Reporting Requirements established from the AR&M Process. Artifact Reporting Requirements establishes the reporting requirements for unidentified, ambiguous, and unresolved artifacts observed in current imagery products.

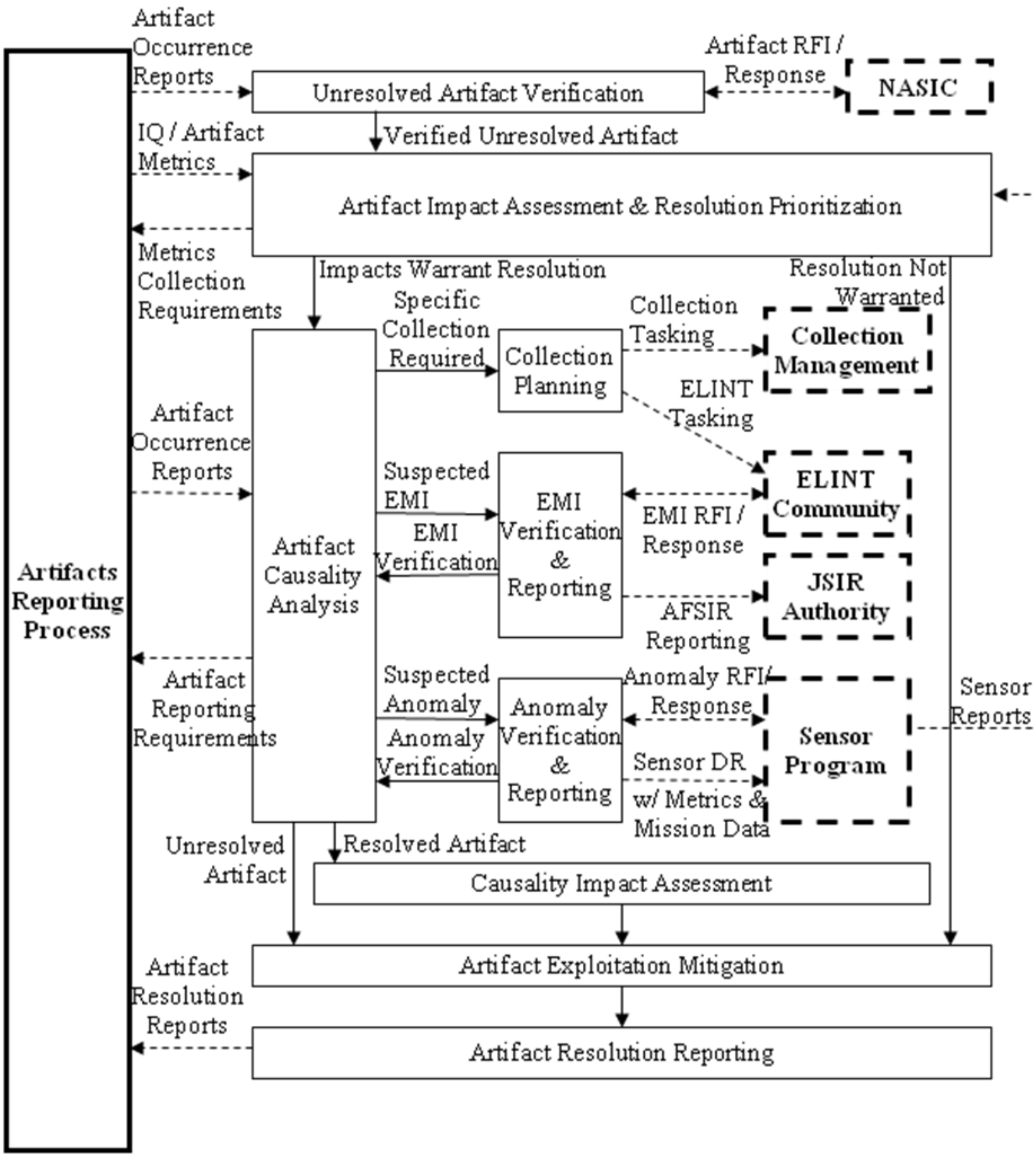
6.4.2.8. EMI Reporting. The objective of EMI Reporting is to conduct reporting of EMI events in accordance with the reporting procedures of AFI 10-707. Only those artifacts observed in current imagery product with sufficiently distinct artifact signature and prior verified EMI resolution shall be used as the basis for initiation of this reporting.

6.4.2.9. Anomaly Reporting. The objective of Anomaly Reporting is to conduct reporting of sensor anomaly events in accordance with the anomaly reporting procedures associated with the sensor involved. The function of Anomaly Reporting is to produce a Sensor Deficiency Report (DR) only for those artifacts observed in current imagery products with sufficiently distinct artifact signatures, and resolution processes indicate the cause is related to the sensor architecture.

6.4.2.10. Metrics Collection. The objective of Metrics Collection is to collect metrics on overall image quality with respect to artifact occurrence and metrics on specific artifact occurrence rates. Metrics are to be collected in accordance with the Metrics Collection Requirements established from the AR&M Process. Image Quality/Artifact Metrics form the basis for determining the relative priorities that specific artifact resolution activities within the AR&M Process are to be conducted. These metrics also determine the overall effectiveness of the Airborne SAR Process in improving Image Quality, as well as determining the overall utility of artifact-riddled SAR imagery products.

6.4.3. Artifacts Resolution & Mitigation Process. The Airborne SAR Artifacts Resolution & Mitigation Process is shown in Figure 6.3. The overall objective of this process is to obtain reports of unresolved artifacts from the Airborne SAR Artifacts Reporting Process, assess the unresolved artifact for its validity, assess its overall impact to image exploitation and assign resolution priority, perform whatever analysis activities are required to resolve the artifact, and initiate or perform whatever mitigation activities are necessary to eliminate the artifact from future occurrence or mitigate its impact on current image exploitation processes. The process begins with the reporting of an unresolved artifact affecting SAR imagery products from the Airborne SAR Artifacts Reporting Process. As stated previously, the process is primarily one of information flow and should include AFISRA, NASIC and the Sensor Program in the circulation of all reports, even if for informational purposes.

Figure 6.3. Airborne SAR Artifacts Resolution & Mitigation Process.



6.4.3.1. Unresolved Artifact Verification. The objective of Unresolved Artifact Verification is to verify the artifacts reported in Artifact Occurrence Reports from the Airborne SAR AR Process as being truly unresolved artifacts (either new or currently existing). To facilitate this, image quality assurance personnel may utilize local information resources, exploitation techniques, and/or the support of NASIC Subject

Matter Experts. Support from NASIC Subject Matter Experts is accomplished through the generation of Artifact RFI / Response Messages. Once the unresolved artifact has been verified, the process proceeds to Artifact Impact Assessment & Resolution Prioritization. At times there is a fine line discerning between an artifact and an anomaly, therefore it is recommended to include the Sensor Program, especially during an event of troubleshooting or resolution.

6.4.3.2. Artifact Impact Assessment & Resolution Prioritization. The objective of Artifact Impact Assessment & Resolution Prioritization is to assess the overall impacts of the unresolved artifact with respect to imagery exploitation processes, determine if its impacts warrant resolution, and to assign a relative priority to its resolution so that ongoing resolution activities can be conducted according to mission priorities. This assessment generally involves an evaluation of the overall effect the artifact has to image product exploitation production versus its occurrence rate as observed in repeatedly collected imagery products. Factors for consideration in this assessment include, but are not limited to: the degree to which the artifact affects exploitation when it occurs in imagery products, the degree to which collection production is affected as a result of repeated collection, the degree to which the artifact affects overall intelligence production and/or impacts mission requirements, and whether or not exploitation mitigation techniques can be used to mitigate imagery product exploitation. If the occurrence rate as observed in imagery products is exceedingly low, the artifact may not be cost effective for resolution. If the artifact is new, as in a first time observance, this assessment and prioritization will have to be postponed until its occurrence in more imagery products can be observed. Metrics collected from the Airborne SAR AR Process (IQ/Artifact Metrics) are necessary for this assessment and prioritization. Should the impact to exploitation or collection processes be assessed as high or exceeding a certain threshold, the artifact is to be assigned a resolution priority. The 480 ISRW supports an activity for anomalies by submitting mission data into the Sensor Program to measure items such as anomaly occurrence rates in their Sensor Reports. This information should also be leveraged as part of the resolution prioritization effort determining what impacts warrant resolution (which includes deciding when to engage the Sensor Program on a Suspected Anomaly). Should the artifact not be of sufficient impact to warrant resolution, it is referred directly to Artifact Exploitation Mitigation. As a result of this impact assessment, the Metrics Collection Requirements may also need to be updated to include or exclude the artifact in/from Airborne SAR AR Process metrics collection. This assessment and prioritization may be repeated as often as necessary if occurrence rates of the artifact in imagery product appreciably change, as reflected in collected IQ/Artifact Metrics.

6.4.3.3. Artifact Impact Assessment & Resolution Prioritization. The objective of Artifact Impact Assessment & Resolution Prioritization is to assess the overall impacts of the unresolved artifact with respect to imagery exploitation processes, determine if its impacts warrant resolution, and to assign a relative priority to its resolution so that ongoing resolution activities can be conducted according to mission priorities. This assessment generally involves an evaluation of the overall effect the artifact has to image product exploitation production versus its occurrence rate as observed in repeatedly collected imagery products. Factors for consideration in this assessment include, but are not limited to: the degree to which the artifact affects exploitation when it occurs in imagery products, the degree to which collection production is affected as a result of repeated collection, the degree to which the artifact affects overall intelligence production and/or impacts mission requirements, and whether or not exploitation mitigation techniques can be used to mitigate imagery product exploitation. If the occurrence rate as observed in imagery products is exceedingly low, the artifact may not be cost effective for resolution. If the artifact is new, as in a first time observance, this assessment and prioritization will have to be postponed until its occurrence in more imagery products can be observed. Metrics collected from the Airborne SAR AR Process (IQ/Artifact Metrics) are necessary for this assessment and prioritization. Should the impact to exploitation or collection processes be assessed as high or exceeding a certain threshold, the artifact is to be assigned a resolution priority. The 480 ISRW supports an activity for anomalies by submitting mission data into the Sensor Program to measure items such as anomaly occurrence rates in their Sensor Reports. This information should also be leveraged as part of the resolution prioritization effort determining what impacts warrant resolution (which includes deciding when to engage the Sensor Program on a Suspected Anomaly). Should the artifact not be of sufficient impact to warrant resolution, it is referred directly to Artifact Exploitation Mitigation. As a result of this impact assessment, the Metrics Collection Requirements may also need to be updated to include or exclude the artifact in/from Airborne SAR AR Process metrics collection. This assessment and prioritization may be repeated as often as necessary if occurrence rates of the artifact in imagery product appreciably change, as reflected in collected IQ/Artifact Metrics.

6.4.3.4. Artifact Causality Analysis. The objective of Artifact Causality Analysis is to perform trend and root cause analyses to attribute an unresolved artifact to its associated causality. Artifact causality analyses are conducted according to the priorities set for the unresolved artifact relative to all other ongoing resolution activities. If specific collection is required to support causality analysis, conduct Collection Planning. If causality analysis results in suspected EMI, perform EMI Verification & Reporting. If causality analysis results in suspected sensor anomaly, perform Anomaly Verification & Reporting. Resolved artifacts resulting from causality analysis are referred to Causality Impact Assessment. Unresolved artifacts for ongoing, long term analyses are referred to Artifact Exploitation Mitigation.

6.4.3.5. Collection Planning. The objective of Collection Planning is to support Artifact Causality Analysis with the development and preparation of Collection Tasking and/or ELINT Tasking where additional IMINT/GEOINT/MASINT collection or coordinated IMINT/GEOINT/MASINT and ELINT collection is required to verify or disprove artifact causality hypotheses in support of artifact resolution.

6.4.3.6. EMI Verification & Reporting. The objective of EMI Verification & Reporting is to support Artifact Causality Analysis with obtaining ELINT data from the ELINT Community that may be required to test (verify or disprove) artifact EMI causality hypotheses in support of artifact resolution. Should EMI causality be proven, this process element will also conduct reporting of the verified EMI event(s) in accordance with the reporting procedures of AFI 10-707.

6.4.3.7. Anomaly Verification & Reporting. The objective of Anomaly Verification & Reporting is to support Artifact Causality Analysis by coordinating with the Sensor Program to obtain data that may be required to test or verify artifact sensor anomaly causality hypotheses in support of artifact resolution. In cases where sensor anomaly is suspected or highly probable, this process element is responsible with coordinating with the Sensor Program on its activities to verify that an anomaly actually exists in the sensor architecture. This process element is also responsible for sharing with the Sensor Program the supporting evidence obtained from Artifact Causality Analysis that led to the reasons to suspect that a sensor anomaly may exist as well as supporting the Sensor Program in examining and testing specific sensor architecture anomaly causality hypotheses against that supporting evidence through further iterations of Artifact Causality Analysis. This process element may also directly generate a Sensor DR based solely on the supporting evidence obtained from Artifact Causality Analysis and the information obtained from the Sensor Program when that evidence is conclusive.

6.4.3.8. Causality Impact Assessment. The objective of Causality Impact Assessment is to assess the overall impacts of the resolved artifact causality with respect to future imagery collection and imagery exploitation processes. This generally depends on whether or not the artifact causality itself is correctable, and if not correctable, whether or not collection and/or exploitation processes can be mitigated to address and/or minimize its repeated occurrence in future collection. Factors for consideration in this assessment include, but are not limited to: is the causality correctable; if the causality is correctable, will it actually be corrected and how long will it take for the corrective action to be accomplished; if the causality is not correctable or will not be corrected, is there some operational causality mitigation that can be employed to minimize its occurrence; and will an exploitation mitigation be required to be developed and employed on an interim or permanent basis. The results of this assessment shall be used as a basis for determining whether or not exploitation mitigation and/or operational causality mitigation will be required to be developed.

6.4.3.9. Artifact Exploitation Mitigation. The objective of Artifact Exploitation Mitigation is to identify any possible tools or advanced exploitation techniques that may be used in the Airborne SAR AR Process to facilitate exploitation of imagery products with the subject artifact present. Such mitigation may be required due to the artifact being not of sufficient impact to warrant artifact resolution, being not resolvable at this point in time, being resolved but not correctable, or being resolved and correctable but not in sufficient time to mitigate its impact to current exploitation and collection processes. The artifact mitigation strategy that is developed as a result of this process element is to be referred to Artifact Resolution Reporting for incorporation into the subsequent Artifact Resolution Report to be generated for the artifact.

6.4.3.10. Artifact Resolution Reporting. The objective of Artifact Resolution Reporting is to produce an Artifact Resolution Report which documents the resolution activity performed on the subject artifact. The Artifact Resolution Report documents all the information relevant to the AR Process for the resolution of the artifact, or for an artifact that is still in the process of resolution. Artifact Resolution Reports may take the form of either final reports, for artifacts that have completed the resolution process, or interim reports, for artifacts that are in the process of resolution. The use of interim reports are for unresolved artifacts that require a long period of time to resolve and support the need to communicate artifact resolution progress and other relevant information to the AR Process, especially with respect to information that the AR process may need to perform more refined artifact signature identification and verification, perform specific local artifact resolution, and any specific requirements for further reporting, and/or potential artifact exploitation mitigation techniques. Artifact Resolution Reports may also be generated for artifacts that are not able to be resolved at the present time or foreseeable future, as well as for fully resolved artifacts, to communicate the same relevant information as for interim reports.

7. Airborne SAR Artifacts Reporting Procedures.

7.1. General. This attachment defines procedures and identifies techniques for the resolution and reporting of artifacts affecting the exploitability of electronic soft-copy imagery products collected and produced by Air Force Airborne SAR platforms. It provides detailed guidance for the implementation of standardized technical and management processes for artifact reporting and resolution actions for affected airborne ISR imagery products. The procedures and techniques are provided as baseline tools to assist image exploitation personnel in the Airborne SAR Artifacts Reporting Process performing artifact resolution and reporting in a timely and efficient manner.

7.2. Airborne SAR Artifacts Reporting Process. The overall objective of the Airborne SAR Artifacts Reporting Process is to identify artifacts within SAR imagery products requiring further resolution, attempting to resolve them with locally available information and resources, and reporting the artifacts that cannot be resolved locally to personnel implementing the Airborne SAR Artifacts Resolution & Mitigation Process. The process begins with Airborne SAR imagery products affected by artifact content—for those SAR imagery products that have no artifact content, normal exploitation processes will be performed.

7.3. Assumptions and Constraints. The following assumptions and constraints affect implementation of the procedures set forth in this attachment into existing SAR imagery exploitation and reporting processes.

7.3.1. Assumptions:

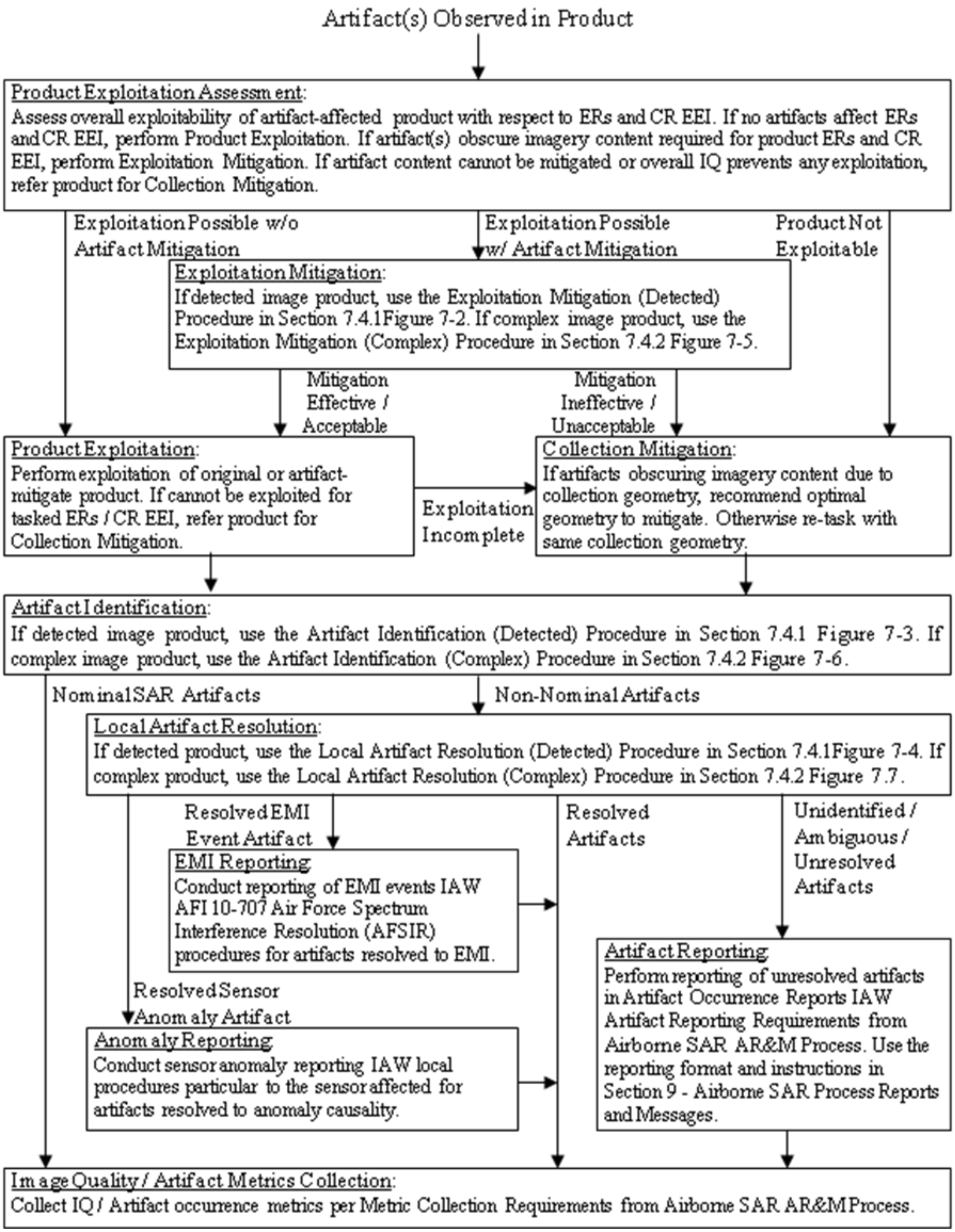
7.3.1.1. Existing SAR Exploitation Processes. This instruction does not circumvent existing techniques and procedures for exploitation of SAR imagery products.

7.3.1.2. AFI 10-707 AFSIR Implementation. This instruction assumes that processes for AFSIR are implemented IAW AFI 10-707.

7.3.2. Constraints: Availability of Complex SAR Imagery Product. Not all Air Force Airborne SAR imagery sensors have the ability to produce complex SAR imagery products. Use of detected imagery products exclusively for these processes represents a severe constraint on the effectiveness to which identification, reporting, resolution, and mitigation can be performed.

7.4. Airborne SAR Artifacts Reporting Procedures. The Airborne SAR Artifacts Reporting Procedure is presented in Figure 7.1. The procedure presented in the figure represents a generalized procedure for both detected and complex imagery products. However, individual procedures for detected and complex imagery products differ in terms of availability of artifact signatures that each product has and how they can be employed in various stages of the process. As such, separate procedures are required for each detected and complex imagery product. The following sections present the detailed procedures for each, detected and complex imagery product.

Figure 7.1. Airborne SAR Artifacts Reporting Procedure.



7.4.1. Detected SAR Imagery Product Procedures. The following figures depict the specific procedures for Artifact Reporting specific to detected imagery products.

Figure 7.2. Exploitation Mitigation (Detected) Procedure.

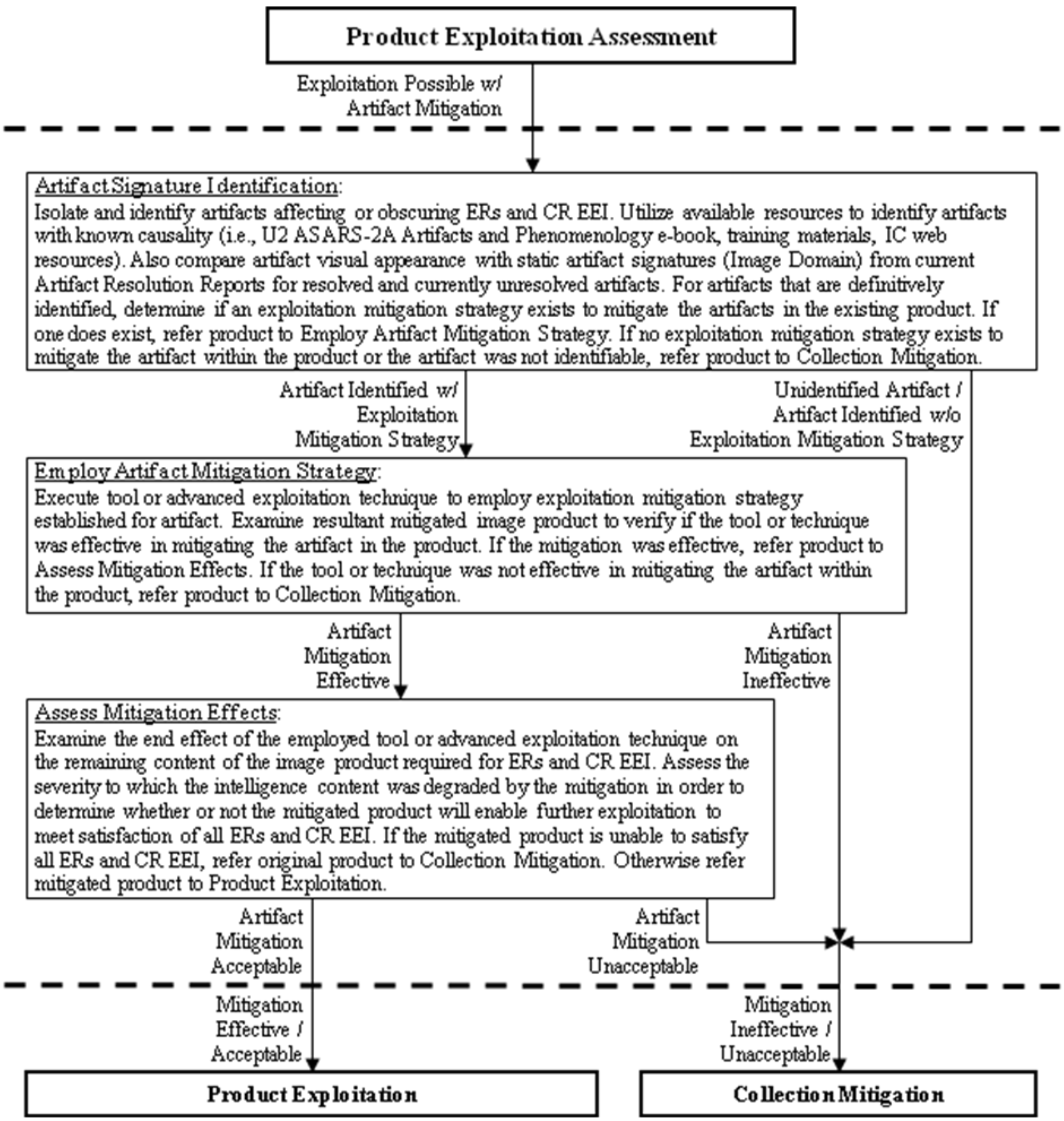


Figure 7.3. Artifact Identification (Detected) Procedure.

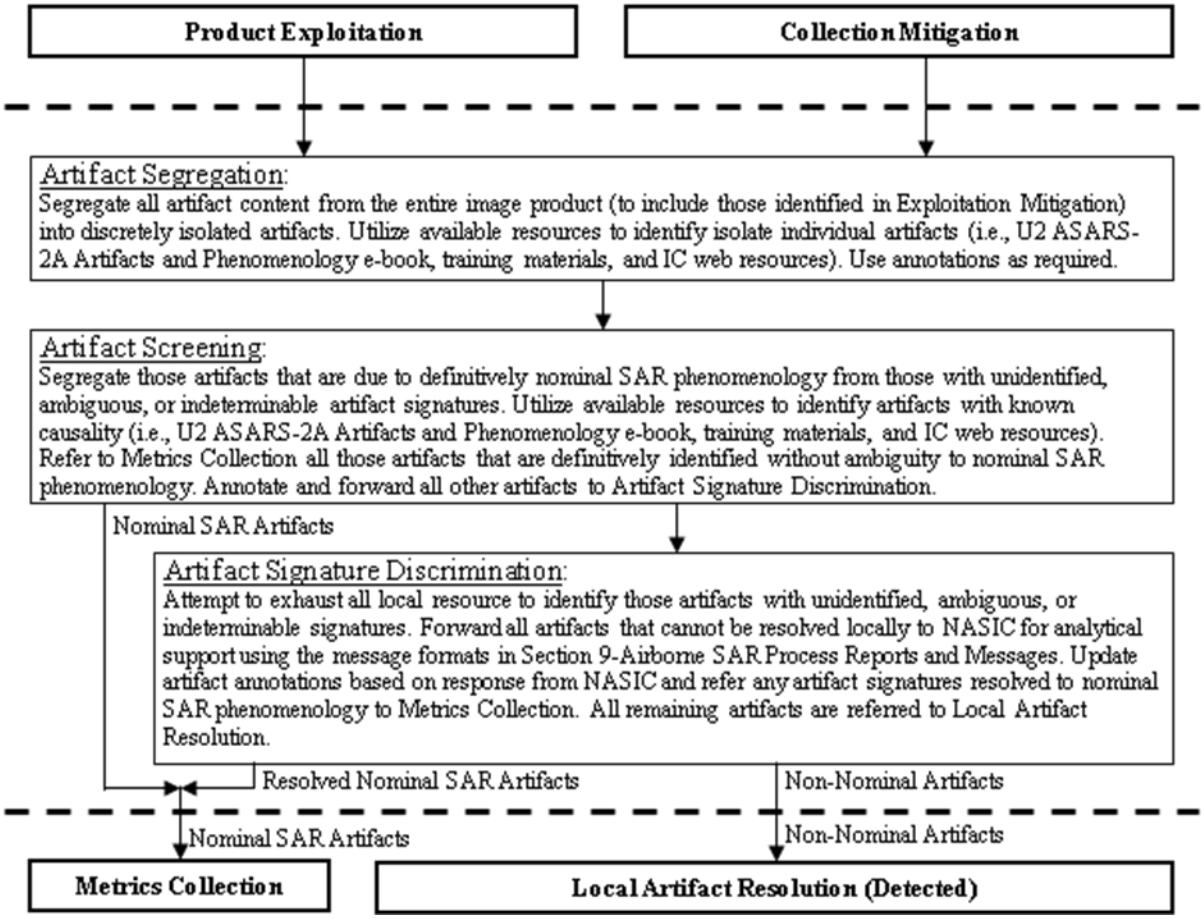
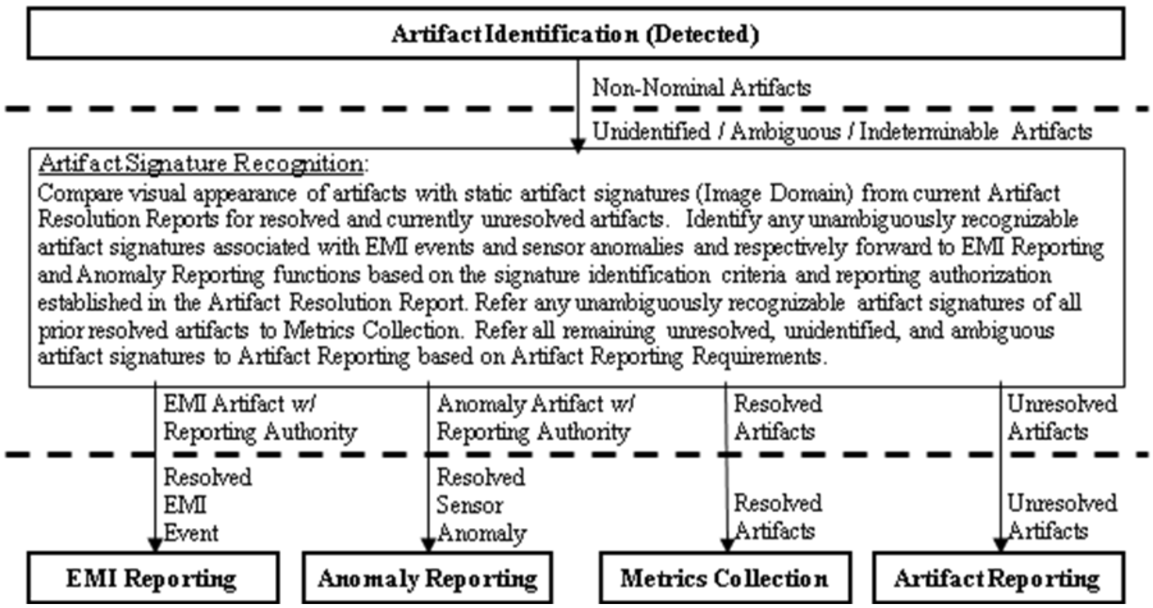


Figure 7.4. Local Artifact Resolution (Detected) Procedure.



7.4.2. Complex SAR Imagery Product Procedures. The following figures depict the specific procedures for Artifacts Reporting specific to complex imagery products.

Figure 7.5. Exploitation Mitigation (Complex) Procedure.

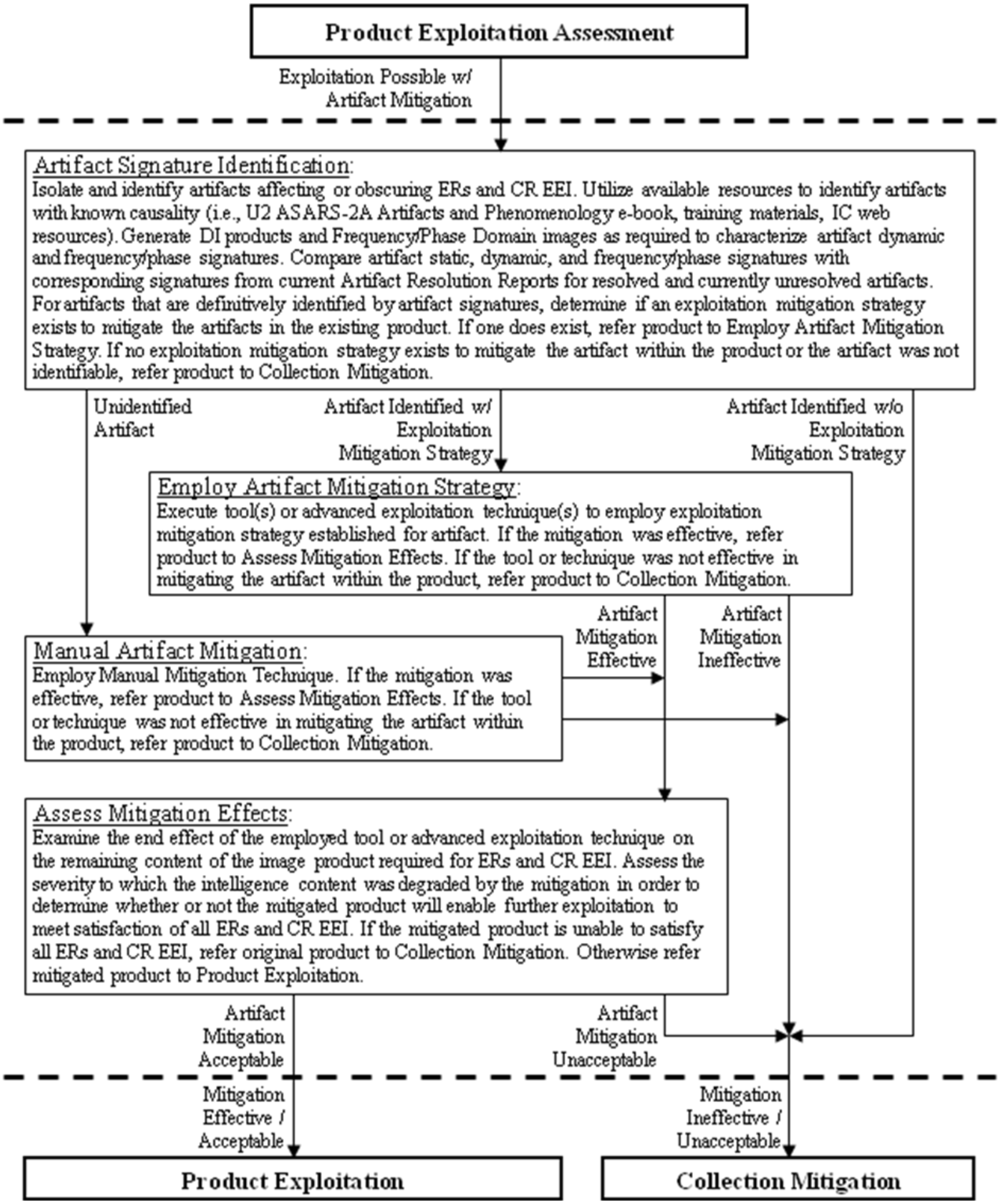


Figure 7.6. Artifact Identification (Complex) Procedure.

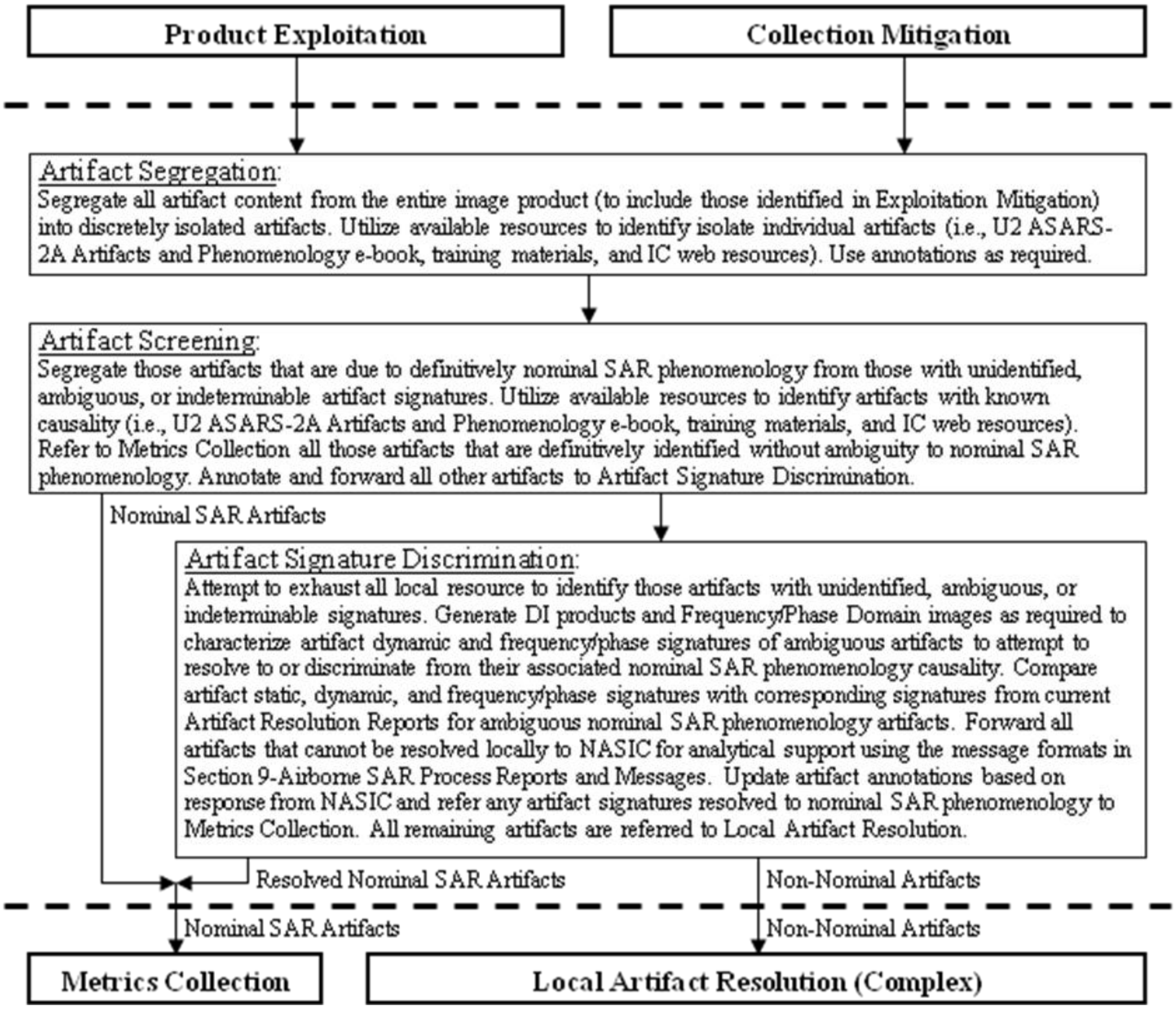
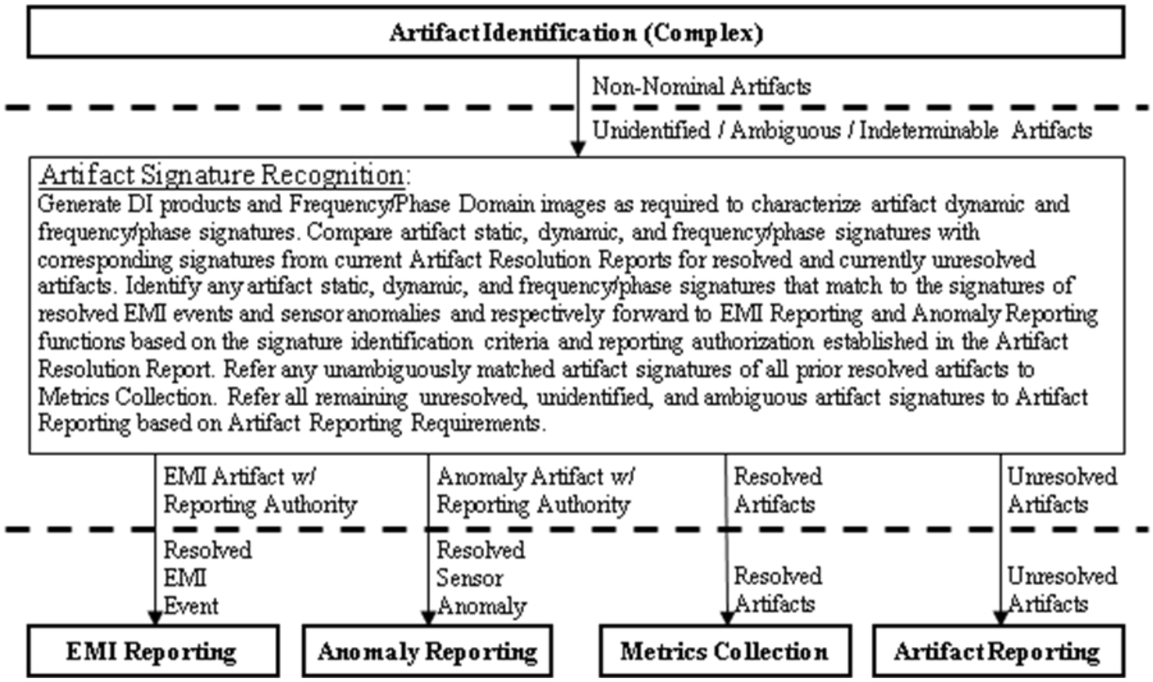


Figure 7.7. Local Artifact Resolution (Complex) Procedure.



8. Airborne SAR Artifacts Resolution & Mitigation Procedures.

8.1. General. This section defines procedures and identifies techniques for the resolution and mitigation of artifacts affecting the exploitability of electronic soft-copy imagery products collected and produced by Air Force Airborne SAR platforms. It also provides detailed guidance for the implementation of standardized technical and management processes for artifact reporting, resolution, and mitigation actions for affected airborne ISR imagery products. The procedures and techniques are provided as baseline tools to assist image quality assurance personnel in the Airborne SAR Artifacts Resolution and Mitigation Process performing artifact resolution and mitigation in a timely and efficient manner.

8.2. Airborne SAR Artifacts Resolution & Mitigation Process. The overall objective of the Airborne SAR Artifacts Resolution and Mitigation Process is to obtain reports of unresolved artifacts from the Airborne SAR Artifacts Reporting Process, assess the unresolved artifact for its validity, assess its overall impact to image exploitation and assign resolution priority, perform whatever analysis activities are required to resolve the artifact, and initiate or perform whatever mitigation activities are necessary to eliminate the artifact from future occurrence or mitigate its impact on current image exploitation processes. More generally, the objective of this process is to NOT necessarily resolve artifacts to the actual technical cause per se, but to resolve artifacts to the circumstances of their associated causalities that may be verified either by confirmation with the sensor program involved or by experimental evidence observed through continuing collected imagery products.

8.3. Assumptions and Constraints. The following assumptions and constraints affect implementation of the procedures set forth in this section into existing SAR imagery quality assurance processes.

8.3.1. Assumptions: AFI 10-707 AFSIR Implementation. This instruction assumes that processes for AFSIR are implemented IAW AFI 10-707.

8.3.2. Constraints: Resolvability of Artifacts. Not all artifacts are resolvable, nor will this process attempt to resolve all artifacts observed in SAR imagery product.

8.4. Airborne SAR Artifacts Resolution & Mitigation Procedures. The Airborne SAR Artifacts Resolution & Mitigation Procedure is presented in Figure 8.1. The following figures represent a step-by-step process for artifact resolution and mitigation. These procedures represent a generalized procedure for both detected and complex imagery products.

Figure 8.1. Airborne SAR Artifacts Resolution and Mitigation Procedure.

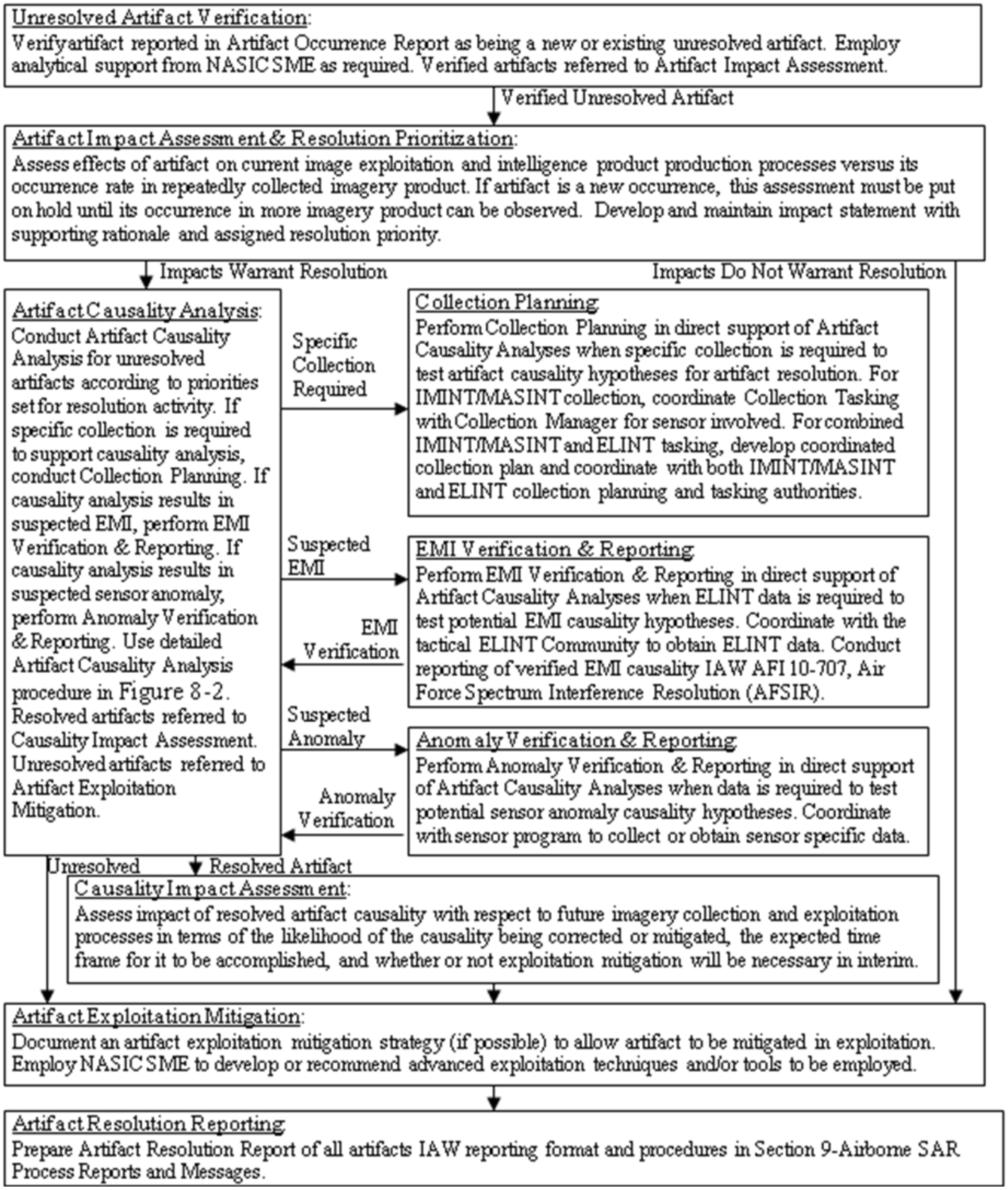


Figure 8.2. Artifact Causality Analysis Procedure.

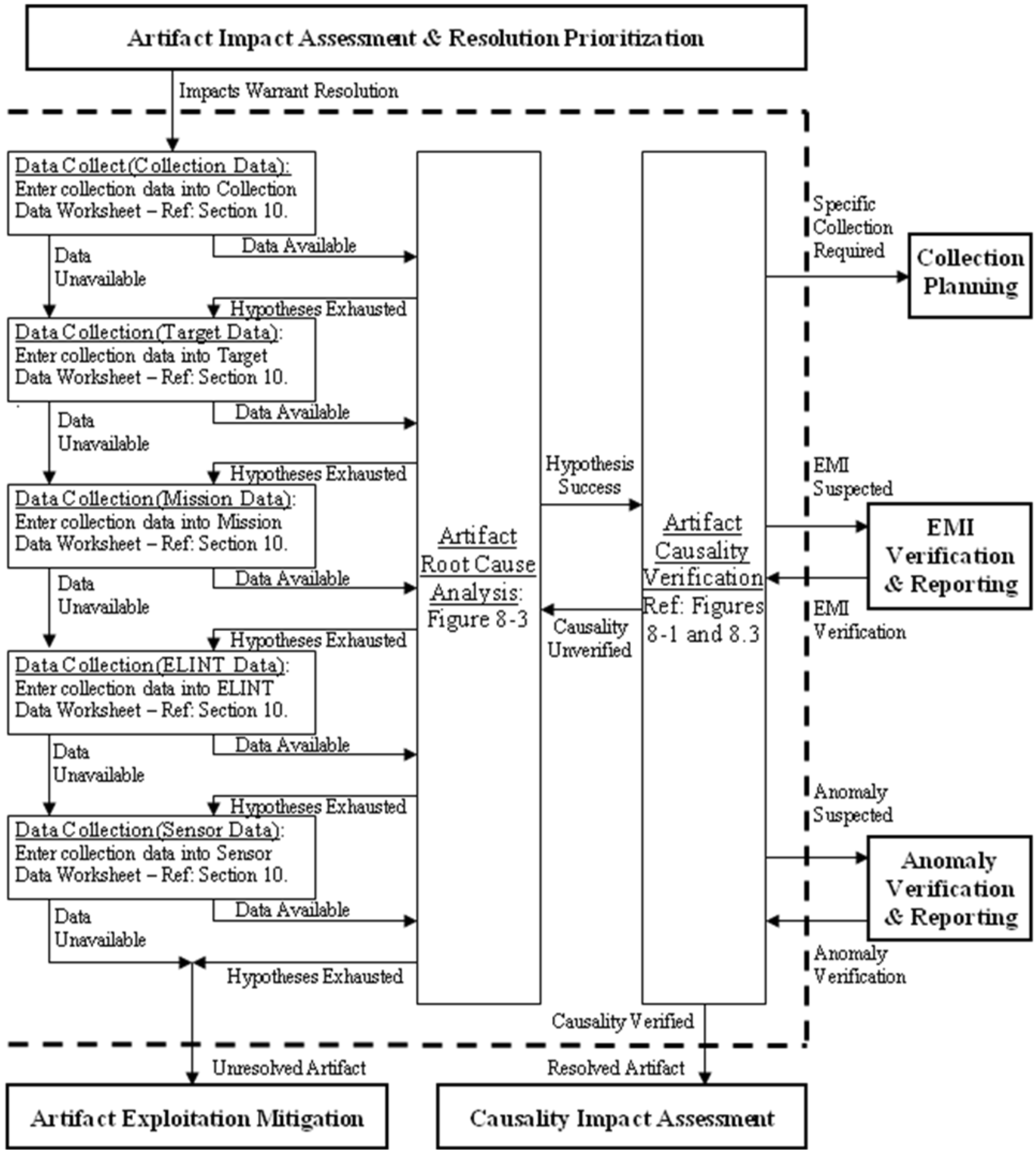


Figure 8.3. Artifact Root Cause Analysis Procedure.

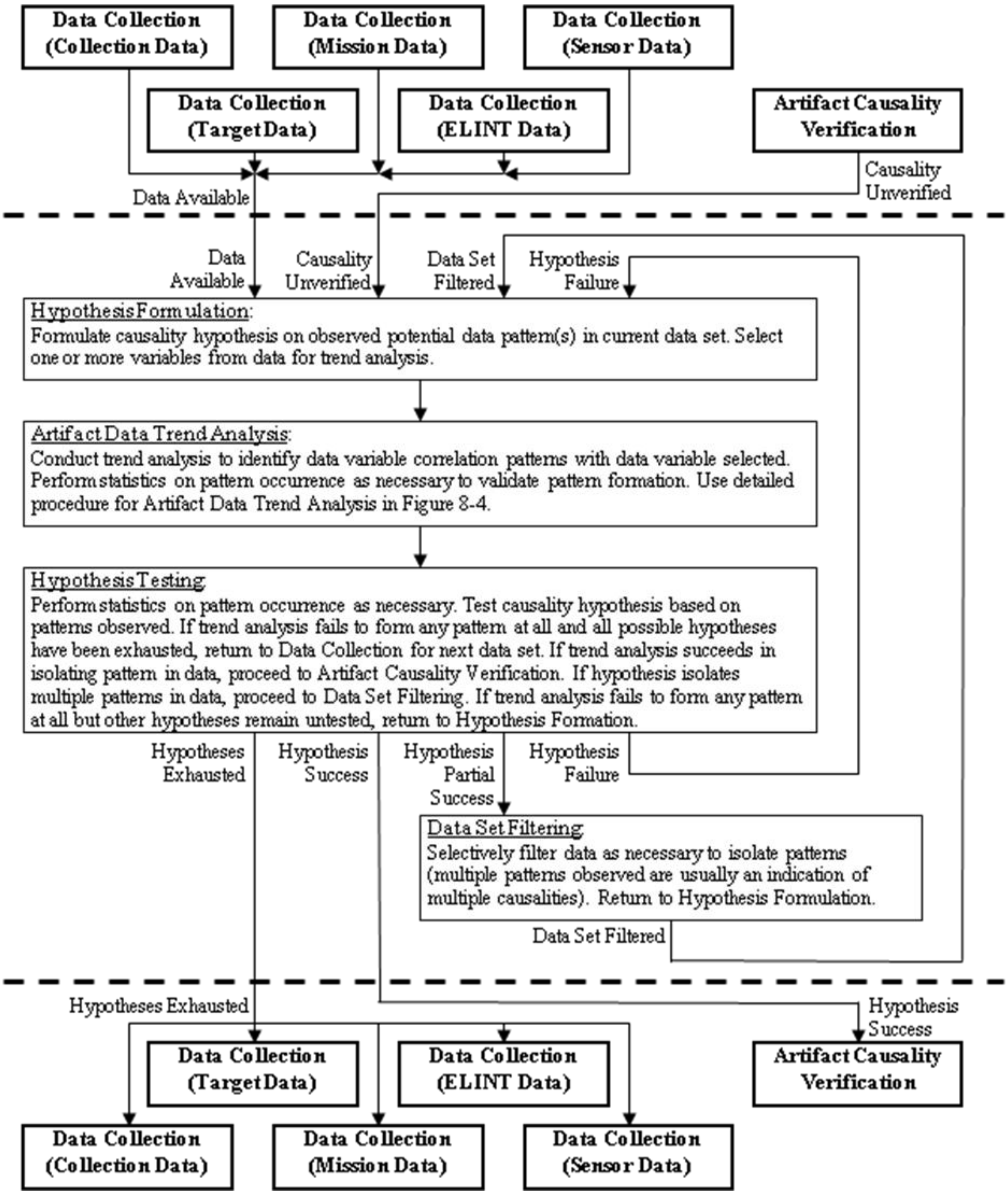
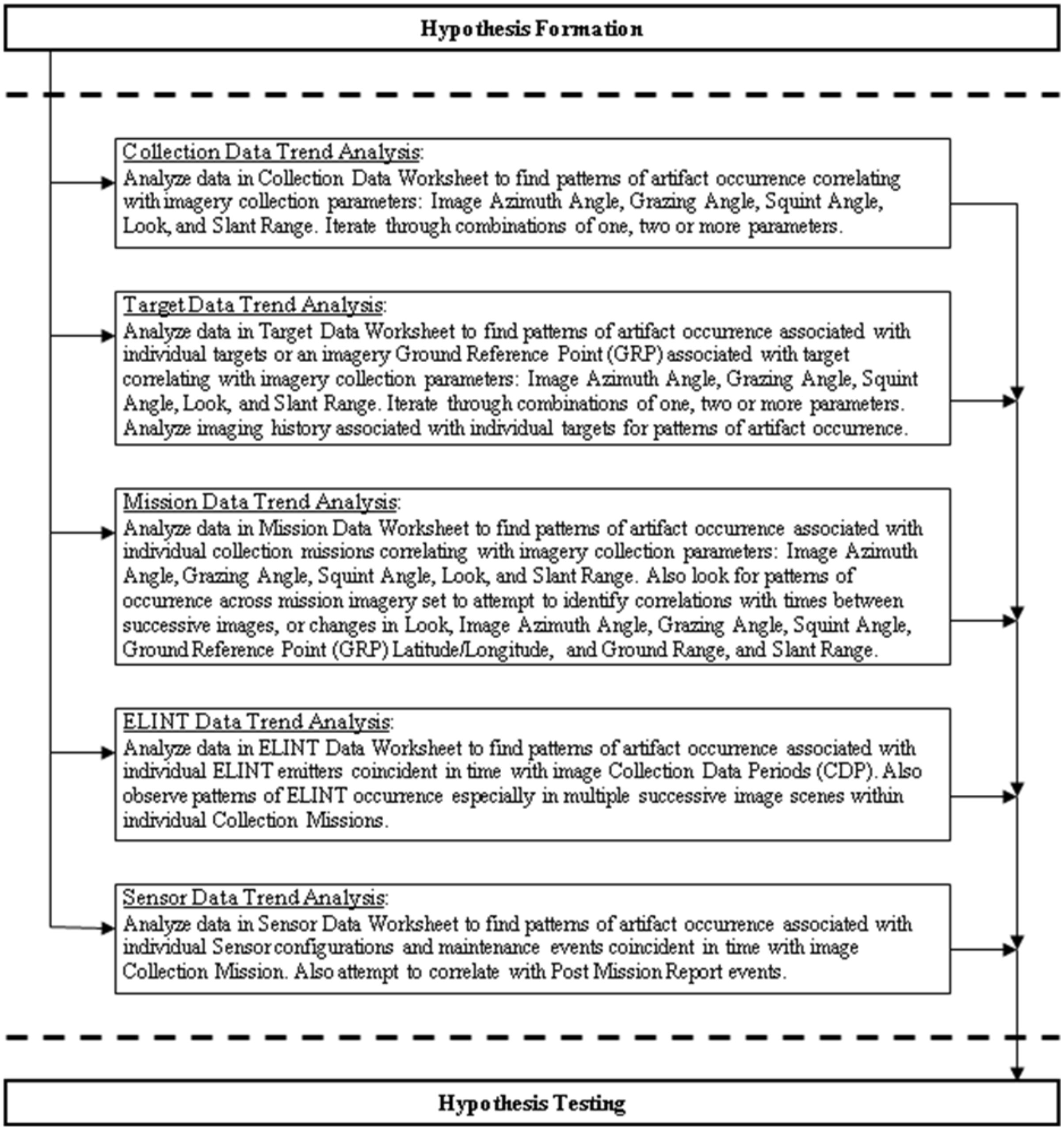


Figure 8.4. Artifact Data Trend Analysis Procedure.



9. Airborne SAR Process Reports and Messages.

9.1. Artifact Occurrence Report. The template for the Artifact Occurrence Report is presented in Figure 9.1, and the report template instructions are presented in Figure 9.2.

Figure 9.1. Artifact Occurrence Report Template.

CLASSIFICATION

Artifact Occurrence Report

1. Date:

2. Artifact Description:

3. Product Affected:

4. Artifact Signature Characteristics:
a. Image Signature Characteristics:

b. Dynamic Signature Characteristics:

c. Frequency/Phase Signature Characteristics:

5. Collection Parameters:

6. Target/Tasked Parameters:

7. Collection Post Mission Report:

8. Product Exploitation Impact:

10. Exploitation / Collection Mitigation Employed:

11. Analysis Checklist (Check all that apply):
a. __ Compared image in question with prior airborne imagery from image archives.
b. __ Compared image in question with prior NTM from image archives.
c. __ Referenced U2 ASARS-2A Artifacts and Phenomenology e-book, or other training materials. (https://intelink.480isrwg.langley.af.smil.mil/DO/IQ/Image_Artifacts/SAR/index_files/index.htm)
d. __ Referenced "image artifacts" WIKI: http://www.intelink.ic.gov/wiki/Airborne_Image_Artifacts, http://www.intelink.ic.gov/wiki/Image_Artifacts,
e. __ Verified that no known aircraft or sensor architecture problem existed from Post Mission Report.
f. __ Reviewed local weather at time of imagery.
g. __ Obtained NASIC SME support.

12. Other Sources Contacted:

13. Analyst Comments:

14. Analyst POC:
a. Name:
b. Phone:
c. Email:

CLASSIFICATION

Figure 9.2. Artifact Occurrence Report Instructions.

Artifact Occurrence Report Instructions

Date:
Provide date and time of report.

Artifact Description:
Provide a general description of the artifact. If artifact is newly observed, provide summary of analysis used to determine this finding and the supporting rationale. If artifact is in process of resolution, reference Artifact Resolution Report used as basis for reporting.

Product Affected:
Provide IID, name of sensor, and collection mode, and type (detected or complex) of product affected. Identify sensor processing architecture used for product collection.

Image Signature Characteristics:
Provide description of identifying and discriminating characteristics of the artifact signature in image product. Attach copy of entire image and image chip (if used), annotated as required to identify artifact.

Dynamic Signature Characteristics:
If artifact found in complex product, provide description of identifying and discriminating characteristics of the artifact dynamic signature from DI product used for characterization (if one is present). Attach copy of DI product and parameters used to generate DI product. Reference if entire image or image chip was used.

Frequency/Phase Signature Characteristics:
If artifact found in complex product, provide description of identifying and discriminating characteristics of the artifact frequency/phase signature from Frequency/Phase Domain analysis (if one is present). Attach copy of Frequency/Phase Domain image. Reference if entire image or image chip was used.

Collection Parameters:
Provide imaging mode and collection parameters (image azimuth, grazing angle, squint angle, imaging look).

Target/Tasked Parameters:
Provide target identification and location (BE or RWAC Number and LAT/LONG coordinates).

Collection Post Mission Report:
Attach any collection Post Mission Report associated with collection mission, if relevant.

Product Exploitation Impact:
If artifact affected or impacted exploitation, describe how it was impacted. Include references to Collection and Exploitation Requirements impacted.

Exploitation/Collection Mitigation Employed:
If exploitation mitigation employed, describe or identify mitigation used. If artifact necessitated re-collection, identify any collection mitigation employed in collection tasking.

Analysis Checklist:
Check all that apply.

Other Sources Contacted:
Indicate names and organizations of other image analysts contacted and their conclusions.

Analyst Comments:
Include any other comments pertinent to analysis performed.

Analyst POC:
Name: Enter Analyst Name, Organization, and Location.
Phone: Enter Analyst Commercial/DNS/NSTS Numbers.
Email: Enter Analyst SIPRNET/JWICS email addresses.

9.2. Artifact Resolution Report. The template for the Artifact Resolution Report is presented in Figure 9.3, and the report instructions are presented in Figure 9.4.

Figure 9.3. Artifact Resolution Report Template.

CLASSIFICATION

Artifact Resolution Report

1. **Report and Resolution Status:**
2. **Artifact Description**:
3. **Products Affected**:
4. **Artifact Signature Characteristics**:
    a. **Image Signature Characteristics**:
    b. **Dynamic Signature Characteristics**:
    c. **Frequency/Phase Signature Characteristics**:
5. **Alternate Artifact Signatures**:
6. **Artifact Identification Criteria**:
7. **Artifact Causality**:
8. **Causality Reporting Authority**:
9. **Exploitation Mitigation Strategy**:
10. **Collection Mitigation Recommendations**
11. **Artifact Misclassification Potential**:
12. **Causality Correction / Mitigation Status**:
13. **Reporting Requirements**:
14. **Point Of Contact**:
    a. **Name**:
    b. **Phone**:
    c. **Email**:

CLASSIFICATION

Figure 9.4. Artifact Resolution Report Instructions.

Artifact Resolution Report Instructions

Report and Resolution Status:

Identify the status of this report as being either interim or final, and the status of the artifact resolution as being either resolved or unresolved. NOTE: Final reports may be created for unresolved artifacts that cannot be resolved.

Artifact Description:

Provide general description of the artifact and its overall impact to imagery exploitation and collection processes.

Products Affected:

Identify imagery products affected by artifact by name of sensor, collection mode(s), and sensor processing architecture(s) used for product collection.

Image Signature Characteristics:

Provide description of identifying and discriminating characteristics of the artifact signature in image product. Include representative example(s) of the nominal signature appearance, annotated as required to identify artifact. Identify any dependencies on collection geometry in signature appearance and expected variations due to geometry.

Dynamic Signature Characteristics:

Provide description of identifying and discriminating characteristics of the artifact dynamic signature (if one is present). Include representative example(s) of the nominal dynamic signature appearance (DI examples). Identify any dependencies on collection geometry in signature appearance and expected variations due to geometry.

Frequency/Phase Signature Characteristics:

Provide description of identifying and discriminating characteristics of the artifact frequency/phase signature (if one is present). Include representative example(s) of the nominal frequency/phase signature appearance (Frequency/Phase Domain image examples).

Alternate Artifact Signatures:

Provide descriptions and examples of alternate artifact signatures and conditions under which they may occur.

Artifact Identification Criteria:

Define minimum identification criteria and any verification requirements, for both detected and complex imagery product, that must be satisfied for artifacts observed in imagery product to be classified as this artifact.

Artifact Causality:

Provide detailed description of the causality associated with artifact. Identify any conditions or patterns of occurrence associated with this causality. If causality has yet to be determined or cannot be determined, identify any conditions or patterns of occurrence associated with the appearance of the artifact in imagery product.

Causality Reporting Authority:

Identify specific authority to conduct EMI or sensor anomaly reporting on the basis of artifact identification in imagery product (consistent with Artifact Identification Criteria). Specifically identify any constraints or limitations on this authority when identifying artifacts solely from detected product.

Exploitation Mitigation Strategy:

If artifact occurrence in imagery product can be mitigated through employment of tools and/or advanced analytic techniques to enable artifact-affected product to be utilized for exploitation, identify specific tool(s) or techniques that should be employed.

Collection Mitigation Recommendations:

Provide recommendations for collection mitigation to reduce or avoid artifact occurrence in repeated collection.

Artifact Misclassification Potential:

Identify any artifacts of other causalities which have potential to be confused or misclassified with this artifact. Identify any distinguishing characteristics or conditions/patterns of occurrence that may be used for distinction.

Causality Correction / Mitigation Status:

Indicate actions that are planned or currently being implemented to mitigate or correct the causality and/or artifact in future occurrence of imagery product, and when they can be expected.

Reporting Requirements:

Indicate if artifact requires reporting in Artifact Occurrence Reports and just recording in Metrics Collection.

Point Of Contact:

Name: Enter Analyst Name, Organization, and Location.
Phone: Enter Analyst Commercial/DNS/NSTS Numbers.
Email: Enter Analyst SIPRNET/JWICS email addresses.

9.3. Artifact RFI Message. The template for the Artifact RFI Message is presented in Figure 9.5, and the message template instructions are presented in Figure 9.6.

Figure 9.5. Artifact RFI Message Template.

CLASSIFICATION

Artifact RFI Message

1. **Date:**

2. **Artifact Description**:

3. **Product Affected**:

4. **Artifact Signature Characteristics**:
   a. **Image Signature Characteristics**:

   b. **Dynamic Signature Characteristics**:

   c. **Frequency/Phase Signature Characteristics**:

5. **Collection Parameters**:

6. **Target/Tasked Parameters**:

7. **Collection Post Mission Report**:

8. **Product Exploitation Impact**:

9. **Exploitation / Collection Mitigation Employed**:

10. **Analysis Checklist (Check all that apply)**:
    a. __ Compared image in question with prior airborne imagery from image archives.
    b. __ Compared image in question with prior NTM from image archives.
    c. __ Referenced U2 ASARS-2A Artifacts and Phenomenology e-book, or other training materials. (https://intelink.480isrwg.langley.af.smil.mil/DO/IQ/Image_Artifacts/SAR/index_files/index.htm)
    d. __ Referenced "image artifacts" WIKI: http://www.intelink.ic.gov/wiki/Airborne_Image_Artifacts, http://www.intelink.ic.gov/wiki/Image_Artifacts
    e. __ Verified that no known aircraft or sensor architecture problem existed from Post Mission Report.
    f. __ Reviewed local weather at time of imagery.
    g. __ Obtained NASIC SME support.

11. **Other Sources Contacted**:

12. **Analyst Comments**:

13. **Nature of Request**:

14. **Analyst POC**:
    a. **Name**:
    b. **Phone**:
    c. **Email**:

CLASSIFICATION

Figure 9.6. Artifact RFI Message Instructions.

Artifact RFI Message Instructions

Date:
Provide date and time of message.

Artifact Description:
Provide a general description of the artifact. If artifact is newly observed, provide summary of analysis used to determine this finding and the supporting rationale.

Product Affected:
Provide IID, name of sensor, and collection mode, and type (detected or complex) of product affected. Identify sensor processing architecture used for product collection.

Image Signature Characteristics:
Provide description of identifying and discriminating characteristics of the artifact signature in image product. Attach copy of entire image and image chip (if used), annotated as required to identify artifact.

Dynamic Signature Characteristics:
If artifact found in complex product, provide description of identifying and discriminating characteristics of the artifact dynamic signature from DI product used for characterization (if one is present). Attach copy of DI product and parameters used to generate DI product. Reference if entire image or image chip was used.

Frequency/Phase Signature Characteristics:
If artifact found in complex product, provide description of identifying and discriminating characteristics of the artifact frequency/phase signature from Frequency/Phase Domain analysis (if one is present). Attach copy of Frequency/Phase Domain image. Reference if entire image or image chip was used.

Collection Parameters:
Provide imaging mode and collection parameters (image azimuth, grazing angle, squint angle, imaging look).

Target/Tasked Parameters:
Provide target/tasked identification and location (BE or RWAC Number and LAT/LONG coordinates).

Collection Post Mission Report:
Attach any collection Post Mission Report associated with collection mission, if relevant.

Product Exploitation Impact:
If artifact affected or impacted exploitation, describe how it was impacted. Include references to Collection and Exploitation Requirements impacted.

Exploitation/Collection Mitigation Employed:
If exploitation mitigation employed, describe or identify mitigation used. If artifact necessitated re-collection, identify any collection mitigation employed in collection tasking.

Analysis Checklist:
Check all that apply.

Other Sources Contacted:
Indicate names and organizations of other image analysts contacted and their conclusions.

Analyst Comments:
Include any other comments pertinent to analysis performed.

Nature of Request:
Describe specific nature of request (identification, confirmation, specific signature characterization, etc.).

Analyst POC:
Name: Enter Analyst Name, Organization, and Location.
Phone: Enter Analyst Commercial/DNS/NSTS Numbers.
Email: Enter Analyst SIPRNET/JWICS email addresses.

10. Airborne SAR Process Analysis Data Worksheets.

10.1. The worksheets referenced in this document were intended to be embedded objects (Microsoft Excel files) to be used for data collection and analysis. Due to AF document publishing guidelines, the embedded files/objects are not accepted or allowed at this publication. A copy of the Data Collection worksheets with Field Definitions (Microsoft Excel files) will be provided to the 480 ISRW and NASIC/DAG for use and storage. Copies can also be obtained from AFISRA/A3O. A sample portion of each worksheet is presented below. Not all fields in the worksheet are shown due to document page size.

Figure 10.1. Collection Data Worksheet.

ID	AZ (nnn.nn)	GZ (nn.nnn)	SQ (nn.nn)	LOOK (L/R)	SL RNG (nnnnnn.nn)	TOT [Z] (hhmmssZ)	CDP START (sssss.mm)	CDP STOP (sssss.mm)	GRP (ddmmssN_dddmmssE)	REAL SQ (nn.nn)
										0
										0
										0
										0
										0
										0

Note: Not all fields in the worksheet are shown due to document page size limitations.

Figure 10.2. Target Data Worksheet.

Target ID (BE#-or-RWAC)	AZ (nnn.nn)	GZ (nn.nn)	SQ (nn.nn)	LOOK (L/R)	SL RNG (nnnnnn.nn)	TOT [Z] (hhmmssZ)	CDP START (sssss.mm)	CDP STOP (sssss.mm)	GRP (ddmmssN_dddmmssE)	ID

Note: Not all fields in the worksheet are shown due to document page size limitations.

Figure 10.3. Mission Data Worksheet.

MSN_SCN	AZ (nnn.nn)	GZ (nn.nn)	SQ (nn.nn)	LOOK (L/R)	SL RNG (nnn.nn)	TOT [Z] (hhmmss)	CDP START (sssss.mm)	CDP STOP (sssss.mm)	GRP (ddmmssN_dddmmssE)	ID	Artifact (Y/N)

Note: Not all fields in the worksheet are shown due to document page size limitations.

Figure 10.4. ELINT Data Worksheet.

ID	MSN_SCN	CDP [s] (sssss.mm)	TOT START (hhmmssZ)	TOT STOP (hhmmssZ)	SRP (ddmmssN_dddmmssE)	ELINT (Y/N)	ELNOT	RF	Pulsed / CW	ELINT Location

Figure 10.5. Sensor Configuration Data Worksheet.

ID	MSN_SCN	MSN_AC_TAIL	KIT#	KIT_CONFIG	KIT_MAINT_DATE	PMR Event (Y/N)	PMR Event Description

11. Airborne SAR Process Subject Matter Experts (SME) List.

11.1. Organizations for Subject Matter Experts and points of contact (POC's) needed to support the Airborne SAR artifact reporting, resolution and mitigation process is presented in Table 11.1. ***Note:*** This table is provided as a template only, with primary SME/POC organizations listed. A detailed/populated SME/POC list will be provided separate from this document to the AFISRA OPR and shall be distributed as deemed appropriate keeping security and classification in mind.

11.2. The SME/POC list should be updated on a routine basis and distributed accordingly.

Table 11.1. Airborne SAR Artifact Process Subject Matter Experts (SME) List.

Contact	Org	Phone	Email
	AFISRA/A3O	DSN: COM:	SIPR: JWICS: JWICS:
	480 ISRW	DSN: COM:	SIPR: JWICS: JWICS:
	NASIC/DAM	DSN: COM:	SIPR: JWICS: JWICS:
	480 ISRW/TDA (SYQAP)	DSN: COM:	SIPR: JWICS: JWICS:
	AFMC 560 ACSG/CCO	DSN: COM:	SIPR: JWICS: JWICS:
	NASIC/DAI	DSN: COM:	SIPR: JWICS: JWICS:
	NASIC/DASE	DSN: COM:	SIPR: JWICS: JWICS:
	NSA/CCS	DSN: COM:	SIPR: JWICS: JWICS:

12. Adopted Form: AF Form 847, *Recommendation for Change of Publication.*

BRADLEY A. HEITHOLD, Maj Gen, USAF
Commander

Attachment 1

GLOSSARY OF REFERENCES AND SUPPORTING INFORMATION

References

AFISRAI 14-121, *Geospatial Intelligence Exploitation and Dissemination Quality Control Program Management*, 30 October 2009

AFPD 14-1, *Intelligence, Surveillance, and Reconnaissance (ISR) Planning, Resources, and Operations*, 2 April 2004

CJCSI 3320.02B1, Classified Supplement to the *Joint Spectrum Interference Resolution (JSIR) Instruction*, 27 Jan 2006

CJCSM 3320.02A, *Joint Spectrum Interference Resolution (JSIR) Procedures*, 16 Feb 2006

AFI 10-707, *Spectrum Interference Resolution Program*, 20 June 2005

AFTTP 3-1.6, *Tactical Employment – Distributed Common Ground System*, 22 June 2006

Sensor Report: ASARS-2A monthly SYQAP performance report

Airborne Product Exploitation Artifacts Handbook, *U2 ASARS-2A Artifacts and Phenomenology*, This softcopy/CD handbook presents information and samples of known SAR image artifacts, to include causation and in some cases a recommended course of action. Initially, the handbook will be hosted on the 480 ISRW/DO/ImageQuality website.

Abbreviations and Acronyms

AFISRA—Air Force Intelligence Surveillance and Reconnaissance Agency

AFSIR—Air Force Spectrum Interference Resolution

AR—Artifacts Reporting

AR&M—Artifacts Resolution and Mitigation

ASAR—Advanced Synthetic Aperture Radar

BE—Basic Encyclopedia

CDP—Collection Data Period

CM—Counter-measures

CR—Collection Requirement

DCGS—Distributed Common Ground Station

DGS—Distributed Ground Station

DR—(Sensor) Deficiency Report

EEI—Essential Element of Information

ELINT—Electronic Intelligence

EMI—Electromagnetic Interference

ER—Exploitation Requirement

GEOINT—Geospatial Intelligence

GRP—Ground Reference Point

IAW—In Accordance With

IFP—Image Formation Processor

IID—Image ID, Image Identifier

IMINT—Imagery Intelligence

IQ—Image Quality

JSIR—Joint Spectrum Interference Resolution

MASINT—Measurement and Signature Intelligence

NASIC—National Air and Space Intelligence Center

QA—Quality Assurance

SAR—Synthetic Aperture Radar

RFI—Request for Information, Radio Frequency Interference

RWAC—Rapid Worldwide Area Collection

TCPED—Tasking, Collection, Processing, Exploitation, and Dissemination

Attachment 2

SAR PHENOMENOLOGY AND CAUSALITY OF ARTIFACTS

A2.1. Fundamentals of Synthetic Aperture Radar.

A2.1.1. Synthetic Aperture Radar (SAR) is capable of producing high quality images of the earth's surface that avoid the daylight and weather limitations of traditional electro-optical imaging systems. SAR imaging systems belong to the class of active sensors in that it produces its own source of energy for scene illumination. Electro-optical imaging systems, on the other hand, belong to the class of passive sensors that are all commonly limited based upon their reliance on the use of external sources of scene illumination—the sun as a source of reflected electromagnetic energy or the energy of heat that is stored and dissipated from imaged materials. Such systems are also subject to the occluding and/or distorting effects of rain and cloud-cover in the atmosphere that interfere with airborne collection in virtually all optical-based systems. SAR circumvents these limitations primarily due to the operating wavelengths from which they typically operate.

A2.1.2. Aside from providing its own source of scene illumination, SAR systems exhibit one further advantage over all passive imaging systems in its ability to take advantage of coherent illumination in its image formation process. Coherent illumination enables an imaged scene to be illuminated by a single point source of radiation using a limited band of frequencies and aligned in phase. This is distinct from non-coherent or incoherent sources of illumination, such as the sun, which in reality consists of a virtually infinite quantity of independent point sources of radiation representing a full spectrum of frequencies. Coherent illumination enables SAR systems to utilize standard signal processing techniques in its image formation process as well as use the principals of interferometry to produce some unique derivative imagery products that incoherent imaging systems cannot—such as digital terrain elevation maps (DTED), coherent change detection (CCD) images, and the like.

A2.1.3. SAR Collection Modes.

A2.1.3.1. Modern SAR systems are capable of producing images from a variety of collection modes. Although each SAR system uses its own naming conventions, fundamentally the operable collection modes come down to variations of two basic modes: Strip Map and Spot-Light. A further third collection mode of SAR often also exists which combines the properties of both Strip Map and Spot-Light modes, generally referred to as Scan mode. Strip Map mode consists of the SAR imaging sensor pointing its antenna at a constant orientation and illuminating a patch of ground as the sensor platform traverses in a straight line direction such that the illuminated patch traces out a long linear strip parallel to the flight path of the platform for as long as the radar is engaged. Spot-Light mode consists of the SAR imaging sensor pointing its antenna at a fixed ground location as the sensor platform traverses its flight path requiring the SAR antenna to be constantly slewed to maintain illumination on the fixed ground patch for as long as the radar is engaged. Strip Map mode images suffer from one distinct disadvantage from virtually all other modes of SAR collection in that they are of limited resolution, determined by the azimuth beam width of the SAR antenna; a particular point on the ground within the imaged strip is illuminated by the SAR antenna beam for only as long as the point remains in the antenna azimuth beam width while the SAR platform traverses the strip. Spot-Light mode images, on the other hand, are capable of much greater resolution due to the fact that the antenna continually slews to keep the targeted patch of ground illuminated as the SAR platform traverses its flight path. Spot-Light mode image azimuth resolutions are only limited by the length of the synthetic aperture flown by the SAR platform during collection. Although the range resolution of both Strip Map and Spot-Light mode collections are tied to the band width of the SAR sensor, they are not dependent on antenna beam width or length of the synthetic aperture flown by the SAR platform. Modern Spot-Light mode images are capable of producing imagery with spatial resolutions that begin to approach that of remote optical imagery.

A2.1.3.2. Scan mode combines the ability of the SAR system to capture an image in the form of a strip but avoids the limitations of Strip Map mode that only collects in a fixed orientation with respect to the SAR platform (i.e., image strips parallel to platform flight path) and with constrained azimuth resolution. Scan mode utilizes the slewing abilities of the SAR antenna like that of Spot-Light mode to enable the SAR system to collect images of ground patch strips of arbitrary orientation with respect to the flight path of the SAR platform as well as to allow the SAR antenna beam to utilize longer dwell times traversing through the targeted ground patch strip to increase the azimuth resolution of the collected image. Scan mode overcomes the dependence of azimuth resolution on azimuth beam width and SAR platform motion of conventional Strip Map mode, however, at the expense of much greater complexity in the image formation process. In general, Scan mode collections produce images of arbitrary geographic areas and in greater resolution than Strip Map mode but at resolutions still below that of Spot-Light mode.

A2.1.3.3. Modern SAR systems generally contain collection modes in one form or another from the fundamental Strip Map, Spot-Light, and Scan modes. Each of these modes has common as well as unique characteristics, advantages, and limitations, each worth detailed discussion in their own right. Although the scientific and technical principles that are used to form images from these individual collection modes have some commonality in principle, the specific techniques that are utilized in each case are distinctly different and the elaboration of the specific techniques involved in each mode is beyond the scope of this document. Spot-Light mode, however, is normally the dominant mode used in virtually all military imaging applications. As such, all further discussions here shall be limited to the Spot-Light Mode of collection using airborne platforms.

A2.1.4. SAR Collection Process. The typical geometry of an Airborne SAR Spot-Light mode collection consists of the antenna beam of the radar looking out of either side of the SAR aircraft platform, in a direction that is nominally pointed orthogonal to its flight path. This direction of radiation propagation is generally referred to as the range direction, whereas the direction that is nominally parallel to the flight path is referred to as the azimuth or cross-range direction. In a typical airborne platform collection, the SAR system periodically transmits a modulated pulse of microwave energy toward a targeted ground patch as the aircraft traverses along its flight path. As the transmitted microwave energy impinges upon the targeted ground patch, the reflective materials illuminated within the patch reflect the transmitted pulse back to the SAR where the aggregated pulse returns are received, demodulated, and stored. The typical Airborne SAR transmits only one pulse at a time and waits for reception of the aggregated pulse returns from all the electromagnetically reflective materials within the illuminated ground patch before the transmission of the next subsequent pulse in the collection. As the SAR platform proceeds along its flight path trajectory, the SAR antenna continually slews its antenna beam maintaining its orientation on the same targeted ground patch. The flight path through which the SAR platform traverses while transmitting and collecting SAR pulse data is referred to as the synthetic aperture of the collection. The assemblage of the received and demodulated pulse data collected is commonly referred to as the Phase History Data. Once the collection is complete, this phase history data is then forwarded to an Image Formation Processor (IFP) for the SAR system for image construction. Based on the storage and processing capabilities of the particular SAR platform collecting, the image formation processor may be on board the platform itself or be located on the ground, in which case the collected phase history data must be down linked to a mission ground station processing facility. At completion, the image formation processor produces as output a reconstruction of the electromagnetic reflectivity of all the geographic points contained within the illuminated ground patch in the form of a two-dimensional non-literal image corresponding to the range and azimuth dimensions of the collection. The detailed process by which this collected SAR pulse data is transformed into this non-literal image representation of the targeted scene electromagnetic reflectivity is the result of complex signal processing techniques.

A2.1.5. SAR Phenomenology. The theoretical means by which images may be constructed from a pulsed radar system is enabled by virtue of three principal factors: the electromagnetic phenomenology of natural and man-made materials to reflect incident electromagnetic radiation, the principles of radar in utilizing complex modulated pulsed signals to capture and preserve range and Doppler information within reflected pulsed signal returns, and the ability of the SAR system to use advanced signal processing techniques and algorithms to process the pulsed signal returns reflected from such materials in a manner that preserves their spatial distribution from the targeted ground patch and interpret them to fine resolution. In essence, a SAR image is a two-dimensional representation of the spatially distributed electromagnetic reflectivity of the reflective materials contained within the three-dimensional scene imaged by the radar.

A2.1.5.1. Reflectivity of Electromagnetic Radiation. The phenomenon which enables imaging to be performed with a SAR system is the physical property of materials in the imaged environment to reflect electromagnetic radiation. Electromagnetic radiation is generally characterized by its frequency content, energy intensity, and electromagnetic polarization. From a technical point of view, the operating principles by which radiation reflects from materials are generally consistent across the electromagnetic spectrum. When electromagnetic radiation encounters a material in the environment, either through the medium in which it is traversing or its incidence upon the surface of a distinct physical object, it undergoes one or more of the processes of reflection, penetration, or absorption. When absorbed into an encountered material, electromagnetic radiation is generally transformed into heat energy within the material. When penetrating through the surface of an encountered material, the direction in which the electromagnetic radiation travels is generally altered by process known as diffraction. When reflected from a surface of an encountered material, the same operating principles that are commonly understood about visible light generally also apply to all radiation across the electromagnetic spectrum—angle of incidence equals angle of reflection. The specific manner in which radiation reflects from the surface of an encountered material, as may be observed in reflected energy, depends on the reflectivity property of the material itself, as well as the physical size of, the contours within, and the orientation of the surface of the material it impinges upon with respect to the wavelength and direction of the incident radiation.

A2.1.5.1.1. Electromagnetic Reflectivity of Materials. The electromagnetic reflectivity of a given material governs the relative amounts of energy reflected from, penetrated through, and/or absorbed into the material from incident radiation. The reflectivity of a material is a fundamental property of matter and generally depends upon its molecular composition as well as the physical state of the matter. Electromagnetic reflectivity is also frequency dependent—the relative amounts of energy reflected, penetrated, and/or absorbed varies based on the frequency content of the incident radiation upon the material. Consequently, a material that happens to be a good reflector in one frequency range may be a poor reflector in another frequency range. In general, the frequency content and polarization of radiation undergoes no alteration in the reflection process due to the reflectivity of the material. However, the intensity of the energy reflected from that of the incident radiation is typically affected by the processes of penetration and/or absorption as a function of the reflectivity of the material.

A2.1.5.1.2. Physical Surface Size. Aside from the reflectivity of the material itself, the most important factor in determining whether or not a material will reflect energy at all is the size of its surface compared to the wavelength of the incident direction of the radiation. The incident surface of the material must be at near the same size or larger than the wavelength of the radiation impinging upon it in order for energy to be reflected. Surfaces or objects of size less than this threshold will not reflect any incident radiation at all regardless of how good of an electromagnetic reflector its material composition may be. In general, the polarization of incident radiation has no affect on the reflection of energy from reflective materials with respect to the physical size of the material surface. The only exception where polarization does affect reflection is when the surfaces of special linearly-oriented surface geometries happen to precisely align orthogonal to the polarization orientation of the incident radiation. In such cases, little or no energy reflects from such material surfaces. As a rule, vertically polarized radiation tends to reflect more from surfaces with more vertically oriented geometry and less from surfaces with more horizontally oriented geometry relative to the direction of the radiation. The converse tends to be true for horizontally polarized radiation with respect to surfaces with horizontally and vertically oriented geometries respectively.

A2.1.5.1.3. Surface Contour Relief. Once the electromagnetic reflectivity and surface physical size criteria of a material have been met, the specific manner in which radiation reflects from a surface of a reflective material is mostly governed by the contour relief present on the surface of the material incident to the radiation. When the wavelength of the incident radiation is large compared to the relative height differences of the contour features within the surface, the surface acts as a mirror-like reflector and creates what is referred to as a specular reflection. When its wavelength is small compared to such contour feature height differences, the surface causes the reflected energy to be scattered and create what is referred to as a diffuse reflection. The amount of scattering present in a diffuse reflection is governed by the relative distribution and severity of the contour relief present in the surface. As such, it is possible for a surface to exhibit relative amounts of both specular and diffuse reflection. A specular reflection typically results in the reflected energy retaining its polarized nature intact from the original incident radiation. A diffuse reflection typically results in the reflected energy being depolarized as well as being scattered, the degree to which is governed by the severity of the contour relief features present in the surface. Surfaces with extreme and densely distributed contour feature content typically result in complete depolarization whereas surfaces with less extreme or dense contour feature content cause only partial depolarization of the reflected energy (i.e., some polarization of the incident radiation retained). Diffuse reflection is generally referred to as backscatter.

A2.1.5.2. Principles of Radar Applied to Imaging.

A2.1.5.2.1. The basic principles of radar underlie all of the phenomenology associated with SAR and have implications in all phases of collection, processing, and interpreting of the images producible by a SAR system. In fundamental terms, a SAR system is a radar system at its core and is governed by the basic principles of radar. Radar systems detect objects by transmitting signals and listening for their echoed returns. Radar determines the distance to which an object is located by measuring the time the signal takes to reach, reflect, and return from the object back to the radar. In radar terminology, this is referred to as radar range. Radar determines the velocity or the range rate to which an object is moving by measuring the difference between the transmitted and received signal frequencies and calculating object velocity based on the Doppler Effect. In radar terminology, this is referred to as radar Doppler. Although velocity and range rate in essence refer to the same phenomenon, the use of which term in a given situation is governed by the specific application of radar. When the radar is stationary with respect to a target that is in motion, the term velocity generally applies. In applications were the radar is moving with respect to a target that is stationary, as in the case of airborne radar imaging, then the term range rate generally applies. In order for radar to simultaneously determine target range and velocity or range rate, the radar signal waveform must embed both timing information—for range determination, and frequency information in order to detect Doppler frequencies.

A2.1.5.2.2. In order for radar to be employed for imaging, there must be some means employed by the radar to enable the mapping of each radar signal return reflected from a material at a specific geographic location on the ground to a relative position within the produced image such that the spatial relationships to all of the remaining geographic locations on the ground within the illuminated scene are preserved in their resultant positions in the image. This is generally accomplished in SAR by exploiting the unique geometry associated with radar signal phase and Doppler as it applies to radar.

A2.1.5.2.3. Phase and Doppler Geometry. A key enabling principle by which radar can be used for imaging within a SAR system is how the individual geometries associated with the phase and Doppler of a radar signal are exploited to transform the data collected by the radar into a non-literal SAR image. The geometry associated with radar signal phase is somewhat different than that associated with radar signal Doppler. The combined geometries associated with phase and Doppler is typically referred to in radar terminology as the phase and Doppler space. It is these geometries which a SAR must exploit in order to transform the data collected by the radar into a two-dimensional image.

A2.1.5.2.4. Geometry of Radar Signal Phase. If an airborne radar was capable of generating its signal in all directions surrounding its location without obstruction, the phase of the radar signal would radiate out uniformly spherical from its point of origin such that any distance from the platform at any given instant of time would be represented by sphere with its center at the platform location itself. If one were to imagine a three-dimensional geometrical grid of radar signal phase surrounding the platform at a fixed instant of time, it would consist of a series of concentric spheres surrounding the platform, all centered at the airborne position of the platform. Furthermore, if this three-dimensional grid was to intersect with the ground, represented by a simple geometric plane, it would be transformed into a two-dimensional grid in the form of a series of concentric circles all centered at the nadir point of the platform position on the ground. In such a scenario, each individual circle in the grid would represent a particular distance from the airborne platform and subsequently a particular phase of the radar signal. This is the general geometry associated with radar signal phase.

A2.1.5.2.5. Geometry of Radar Signal Doppler.

A2.1.5.2.5.1. The geometry associated with radar signal Doppler is somewhat different from that associated with radar signal phase. If an airborne radar platform was capable of generating its signal in all directions surrounding its location without obstruction and from a stationary point in space without motion, the frequency of the radar signal would also radiate outward in a uniformly spherical pattern like that for radar signal phase—constant in all directions. However, airborne radar platforms are not stationary, and the specific manner in which the frequency of a radar signal radiates out in any specific angular direction relative to the direction of the moving platform behaves according to the Doppler Effect. For a given radar signal radiating out in a particular angular direction relative to the direction of platform motion, its frequency will exhibit a determinably fixed Doppler shift based on the relative velocity of the platform as would be observed along that angular direction. Such would also be true for any orientation of that angular direction around the axis of platform flight trajectory. As such, if that same angular direction were to be orthogonally rotated around the platform along the axis of its flight trajectory, it would form the geometric shape of a cone with the apex of the cone located at the platform position. This is what is generally referred to in radar terminology as the Doppler cone, with the angle used to form the cone at the apex being referred to as the Doppler cone angle. Just as in radar signal phase with values of constant phase being observable on every point on the surface of a sphere, all points on the surface of a particular Doppler cone will exhibit the same Doppler shift in frequency for a radar signal observed to be radiating in the direction that follows along the surface of that cone directed from its apex.

A2.1.5.2.5.2. In general, the lesser the Doppler cone angle with respect to the direction of platform motion, the smaller the Doppler cone becomes and the more positive the Doppler shift will be as experienced by a radar signal observed at any point on the surface of that cone, until reaching zero degrees where the Doppler cone becomes transformed into a line directly aligned with the direction of platform motion and the Doppler shift experienced by the radar signal becomes at its positive maximum. As the Doppler cone angle increases up to 90 degrees, the larger the Doppler cone becomes and correspondingly the smaller the positive Doppler shift will become as experienced by a radar signal observed at any point on the surface of that cone. When the Doppler cone angle reaches 90 degrees, a direction that is perpendicular to the direction of platform motion, the Doppler cone ceases to be a cone and becomes transformed into a flat plane centered at the platform location and the Doppler shift experienced by the radar signal becomes zero. When the Doppler cone angle increases beyond 90 degrees relative to the direction of platform motion, the Doppler cone becomes large again, but in the direction opposite to the flight direction of the platform, and the Doppler experienced by the radar signal begins to shift in the negative direction because the platform is observed to be moving away from that angular direction. As the Doppler cone angle increases from beyond 90 degrees up to 180 degrees, the Doppler cone becomes decreasingly smaller and the corresponding Doppler shift experienced by the radar signal observed at any point on the surface of that cone continues to get more negative until reaching exactly 180 degrees, where the Doppler cone again becomes transformed into a line directly aligned away from the direction of platform motion and the Doppler shift experienced by the radar signal becomes at its negative maximum.

A2.1.5.2.5.3. If one were to imagine a three-dimensional geometric grid of Doppler surrounding the platform at a fixed instant of time, it would consist of a series of concentric Doppler cones surrounding the platform along its forward and reverse directions of travel, each with its apex at the airborne position of the platform. Furthermore, if this three-dimensional grid was to intersect with the ground, represented by a simple geometric plane, it would be transformed into a two-dimensional grid in the form of a series of concentric hyperbolas fanning out in both directions from nadir point of the platform position on the ground. In such a scenario, each individual hyperbola in the grid would represent a particular value of relative range rate from the airborne platform, and subsequently a particular value of Doppler shift as would be observed in a radar signal anywhere along that grid line. This is the general geometry associated with radar signal Doppler.

A2.1.5.2.6. Phase and Doppler Geometry in Space. If the individual geometries associated with radar signal phase and Doppler are overlaid into the same volume of geometric space surrounding the position of an airborne radar platform, the combined three-dimensional geometric space would consist of concentric spheres interlaced with concentric cones centered at the position of the airborne radar platform in that space. Attempting to use this combined phase and Doppler geometry in three-dimensional space, however, can produce some unusual affects in terms of radar signal interpretation. For example, when the geometry associated with a particular radar signal phase—the sphere representing points of equidistant phase, intersects with the geometry associated with a particular radar signal Doppler—the Doppler cone representing the points of equal Doppler shift, the net intersection is a circle with its center and orientation located along and perpendicular to the path of travel of the airborne platform. As such, all of the points on this circle represent a possible instance of a radar signal with the exact same phase and Doppler shift characteristics. If a radar signal were to intercept with and reflect from an object located at any point on this circle, the reflected radar signal would have the exact same signal phase and Doppler-shifted frequency characteristics. This makes it impossible for a reflected radar signal having a particular combination of signal phase and Doppler-shifted frequency characteristics to be attributable to a unique spatial position. This is generally known in radar terminology as ambiguity. Ambiguity represents problems in any radar application because it prevents a specific radar signal return to be uniquely attributed to whatever physical quantity the radar is measuring (i.e., range, velocity, location, etc.). All applications of radar inherently have ambiguities. In SAR, the ambiguity scenario described above generally explains the presence of signatures within SAR imagery such as the layover effect from elevated targets and the affects of objects in motion within or near the target imaged area. The challenge of using radar in any application generally requires the radar to be used in a manner which reduces or at least limits its inherent ambiguities.

A2.1.5.2.7. Phase and Doppler Geometry in the Ground Plane. Although the combined geometry associated with radar signal phase and Doppler is entirely unsuitable when applied to the three-dimensional space surrounding an airborne radar platform due to the nature of the radar ambiguities it presents, it becomes more suitable when it is limited to applying to the intersecting two-dimensional ground plane of the earth. Such an intersection produces onto the ground plane a grid of concentric circles interlaced with concentric hyperbolas, all centered at the nadir point of the airborne radar platform projected onto the ground. This grid can in effect be used to represent a two-dimensional coordinate system of radar signal phase and Doppler on the ground plane. This limited geometry of radar signal phase and Doppler applied to the ground plane in effect enables every point in the ground plane relative to the airborne radar position to have an almost unique radar signal phase and Doppler associated with it. The reason why radar signal phase and Doppler is not entirely unique, however, is due to a residual radar ambiguity produced by the curvature of the phase and Doppler lines within the composite phase and Doppler grid. This grid curvature results in exactly two spatial points on the phase and Doppler grid for every unique coordinate value of signal phase and Doppler, positioned symmetrically equidistant on each side of the nadir line the path and motion that the airborne platform makes onto the ground plane. This is not detrimental if the radar onboard the airborne platform is employed to collect from only either side of the platform at a time with respect to the nadir line associated with its path of motion. In doing so, the ground plane is essentially split into two parts, one on each side of the airborne platform, and thus eliminating the radar ambiguity. This is the fundamental reason which SAR collections are only performed from the perpendicular sides of collection platforms relative to its direction of travel. Doing so allows for each unique coordinate value of radar signal phase and Doppler to be attributable to one and only one unique spatial point in each half plane. As a result, the limited geometry of radar signal phase and Doppler applied to each ground half plane in effect enables every point in each half plane relative to the airborne radar position to have an unambiguously unique radar signal phase and Doppler associated with it.

A2.1.5.3. Phase and Doppler Content of Radar Signal Returns.

A2.1.5.3.1. Radar Signal Phase and Doppler Content Preservation. Another key enabling principle by which radar can be used for imaging within a SAR system is how complex modulated pulsed signals incorporate and preserve the range and Doppler information within reflected pulsed signal returns. In the typical air-to-ground airborne radar collection scenario, as a radar signal generated from the platform radiates toward a particular geographic position on the ground, the position and motion of the platform relative to that ground position at the exact instant the signal was generated causes the frequency content of the radar signal to be shifted in frequency according to the Doppler Effect. As such, when the radar signal reflects from a material surface at that particular ground position and returns back to the platform, it does so retaining its distinctive Doppler-shifted frequency content. Together with the amount of the time necessary for a generated radar signal to propagate to and return from a particular ground position, the specific phase and Doppler information embedded and retained within a reflected radar signal facilitates its direct attribution to that specific geographic position on the ground relative to the exact position, velocity, and direction of travel at the exact time the radar signal was generated.

A2.1.5.3.2. Radar Signal Segregation. Aside from the preservation of the spatial relationships amongst imaged scene content, the detection of embedded phase and Doppler information content from reflected radar signal returns is also critical to SAR for radar signal return segregation. In the typical SAR collection scenario, a SAR generates a single pulsed signal and collects the aggregated signal returns reflected from materials in the illuminated target area. Because most of the materials within the illuminated target area are collocated, the signal returns reflected from those materials are overlapping with respect to both time and frequency. Without any ability to segregate the overlapping radar signals returned from such a collection, image formation would be impossible. Since the geometry of radar signal phase and Doppler on the ground plane causes each distinct geographic position with the ground plane to have a unique and unambiguous signal phase and Doppler characteristic in the reflected radar signal return, each of the reflected signal returns in the aggregated return have unique and unambiguous embedded signal phase and Doppler information content. This unique and unambiguous embedded phase and Doppler information content enables the radar to distinguish each individual return from each other with the use of signal processing techniques.

A2.1.5.3.3. Imaging Radar Signal Waveform. Radar is capable of detecting both phase and Doppler information from reflected radar signal returns provided that sufficient phase and frequency content is encoded into the signal used by the radar. The choice of the signal waveform to be used in a radar system is perhaps the single most governing property in determining its resolution capabilities and limitations. The typical modern SAR system utilizes a specially modulated pulse, called the Linear FM Chirp, as its transmitted pulse waveform. The Linear FM Chirp is characterized as a signal waveform where the frequency starts at some starting value and increases in a linear fashion until reaching an end value. The rate with respect to time to which frequency increases is referred to as the Chirp Rate of the signal. The Linear FM Chirp signal belongs to the class of Coded Waveforms in Signal Processing that have their own associated set of signal processing techniques. The Linear FM Chirp represents one kind of coded waveform known as a Dispersed Waveform and its associated signal processing technique known as Pulse Compression. The Linear FM Chirp represents one way to encode a radar signal with greater effective bandwidth that can be effectively used to achieve high range resolution without the negative radar system consequences of attempting to use CW burst pulse waveforms. The utility of using the Linear FM Chirp waveform, especially in imaging radars, comes about because the duration of this signal can be made long compared to that of a CW burst pulse signal, yet have the same effective bandwidth. The Linear FM Chirp is perhaps the most utilized of large time-bandwidth product waveforms in imaging radars. Given that the range resolution of a radar is determined by the bandwidth of the transmitted waveform, use of the Linear FM Chirp waveform in place of the CW burst pulse achieves the same effective resolution, but with more energy per pulse, which translates to a corresponding increase in signal-to-noise ratio in the captured radar image and a corresponding increase in image quality such as contrast.

A2.1.5.4. Image Formation Process.

A2.1.5.4.1. Fundamentally, the content within a SAR image is controlled by how the SAR image formation processor interprets the demodulated pulse data returned to the radar during the collection process. As such, the quality and accuracy of that SAR image content in representing the true electromagnetic reflectivity of the targeted scene being imaged is dependent upon the quality and accuracy to which the pulse data returned to the radar is preserved in all of the processes in the image processing chain starting from pulse signal reception at the antenna all the way through to production of the final image. A SAR imaging system is fundamentally a radar system, and as such, is subject to the same imperfections as most electronic systems are, to which the disciplines of engineering and manufacturing attempt to manage and control. Given the current state-of-the-art, such imperfections are unavoidable, but are managed within the context of the system design to be within limits that are acceptable such not to impact performance of the overall system so long as the operating constraints for which the imperfections were mitigated to are observed and adhered. Some imperfections are static in nature and are only mitigated through the static design of the system. Other imperfections are dynamic in nature and have to be managed through special one-time or continuing calibration to control and compensate for the imperfections to keep them within the tolerable limits necessary for proper and expected system operation. Those imperfections which cannot be mitigated through static design or dynamic management are generally mitigated only by direct manipulation of the actual collected data through the means of algorithmic compensation (i.e., performed in the image formation processor). Nonetheless, even with proper system design and calibration, system imperfections may still arise from time to time to levels that impact operation of the system due to fatigue and/or failure of system components, calibration drift, or unforeseen conditions for which designed mitigations cannot manage or control. ***Note:*** All of these factors have the potential to affect the quality and accuracy of the contents of the final image product from a SAR imaging system.

A2.1.5.4.2. Beyond these aforementioned issues associated with SAR imaging system hardware, there are also potential issues associated with the image formation process—the term that is generally used to represent the set of complex algorithms utilized to transform returned radar pulse data into SAR images—that also must be addressed.

A2.1.5.4.3. In addition to transforming the collected radar pulse data into the final SAR image product, these algorithms must also perform tasks such as manipulate the collected pulse data into a form that facilitates its processing with conventional signal processing techniques, compensate for the errors in collected radar pulse data induced from SAR system hardware imperfections (as mentioned previously), compensate for the residual signal processing errors resulting from demodulation of collected radar pulses, compensate for effects on collected radar pulse data induced from imperfections in SAR platform flight path trajectory encountered during collection, compensate for imperfections inherent in the specific image formation algorithm chosen for image formation processing, compensate for the resultant geometric distortion present as a result of collection geometry, and perform transformation processes designed to negate the defocusing effects of collection geometry and improve the overall focus and/or quality of the final image product.

A2.1.6. SAR Image Interpretation.

A2.1.6.1. Radar images have properties that are distinctly different from those of optical-based images. Proper interpretation and information extraction from SAR images requires a fundamental understanding and appreciation of at least some of these properties. SAR image properties fundamentally fall into two types or categories: extrinsic—where properties of the scene being imaged produce effects in the resultant image independent of the radar system, and intrinsic—properties that are generated purely by the radar system itself and the signal processing involved in the image processing chain.

A2.1.6.2. All properties have some effect in the quality of the resultant image product, some more than others. System intrinsic properties are significant in their ability to affect the extrinsic image properties generated by the external world. The SAR system can modify, distort, or produce uncertainties in the extrinsic properties of the scene being imaged. Further distinction must also be made between intrinsic properties of the SAR imaging system, which cannot be overcome, and artifacts produced by errors or inadequacies in the behavior of the imaging system and its associated signal processing.

A2.1.6.3. In terms of SAR systems, only reflections from specular surfaces with orientations perpendicular to the pulsed signal generated by the radar return to the radar. Such reflections appear as light areas within a SAR image—the stronger the return, the whiter the area in the image. Given that electromagnetic energy reflections from all other specular surface orientations relative to the radar is reflected away from the radar, such reflections appear as completely dark areas within a SAR image. Diffuse surfaces with all but extreme surface orientations away from the radar all provide some backscatter signal energy returned to the radar. Diffuse reflections are usually appear as various tones of gray in SAR images, with darker tones representing weak signal returns and lighter tones representing stronger signal returns. Not much exploitation value can be gained from interpreting the specific shade or tone of gray represented in an image as the electromagnetic reflectivity, surface texture, and surface orientation all play a part in determining the amount of backscatter energy returned in a reflection from a diffuse surface, and these factors cannot be distinguished from one another without a priori knowledge of the content of the imaged scene. In general, the diffuse reflections represented in a SAR image generally bring context to the specular reflections represented in an imaged scene. As for surfaces or objects with surfaces that are small compared to the wavelength of the SAR system, such surfaces do not reflect electromagnetic energy, regardless of electromagnetic reflectivity of the material involved. The consequences for a SAR imaging system are that surfaces of such size would not be visibly apparent in SAR imagery products because they are not discernable to the radar.

A2.1.6.4. In regards to polarization, specular reflections from surfaces which happen to alter the polarization orientation of the returning electromagnetic energy, either from direct or multi-path reflection, may negate the ability of the SAR system to collect the returned pulse by the fact that the polarization of the antenna prevents or attenuates its detection based on how the polarization was modified in the reflection process. Such surfaces may in effect appear as an absorber or diffuser of electromagnetic energy to the SAR system rather than the true specular reflector that it actually is. As a result, some SAR systems are designed with the ability to generate both vertically and horizontally polarized radar signals, as well as the ability to collect in cross-polarized configurations (i.e., transmit in one polarization and receive in the other) in order to enhance collection capability. Typically, Airborne SAR systems possess the capability to operate in one polarization only, and that polarization tends to be vertical.

A2.1.6.5. In general, SAR systems are designed to operate in the radio frequency (RF) portion of the electromagnetic spectrum, most predominantly in the X-Band frequency range (8.5-10.6 GHz) with wavelengths near 3 cm (actual 2.8-3.5 cm). In terms of electromagnetic reflectivity at these wavelengths, man-made surfaces and structures made from metal and masonry are good specular reflectors. Surfaces such as roads or runways turn out to be highly specular reflective surfaces due to their surface textures being smooth in comparison to a 3 cm wavelength. This is contrasted to the appearance of roads and runways as diffuse reflections in EO systems which operate in the regions around the visible light portion of the electromagnetic spectrum with wavelengths at around 0.4 to 0.7 micrometers. Water in its liquid form as in bodies of water is also a highly specular reflector. This is contrasted with water in vapor form (as in clouds) or in light to moderate rain, which is for all practical purposes reflectively invisible at RF wavelengths. Wavelength is the primary reason that enables SAR systems to penetrate or look through cloud cover and forms of moderate weather. Wood, if extremely dry, as well as other dry materials such as canvas and netting, are poor reflectors and generally transparent to SAR. However, should structures or surfaces of poor reflectors should become wet or subjected to a film of dirt, oil or debris, they can become excellent reflectors.