White Paper

Holistic, Problem-Centered Approach and Deliberate R&D: How to Generate New Strategies for Nuclear Weapons Proliferation Intelligence

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Introduction

The threat of nuclear weapons proliferation to the United States, its allies, and the greater international community extends beyond the traditional great power competition with Russia and China. Former non-nuclear nations and those with relatively nascent capabilities, especially Iran and North Korea, are developing and enhancing their nuclear weapons capabilities, despite international objections.[1] With the low-level conflict the US is in with these autocratic nations, there is great interest in knowing what actual capabilities they possess. Uncertainty to the exact infrastructure and fissile material output related to the development of nuclear weapons and their delivery systems impedes assessments of their nuclear capabilities. In part, this can be attributed to illicit activities stemming from undisclosed sites or covert operations of said facilities.[2] However, this uncertainty mostly stems from the eroding nuclear weapons proliferation intelligence capability of the US Intelligence Community (IC) since the end of the Cold War.[3]

According to Oedewalt, nuclear weapons proliferation intelligence was the focus of the IC during the Cold War.[4] The dissolution of the USSR and the end of the Cold War introduced the erroneous idea nuclear weapons proliferation was no longer a major threat to US national security. Accordingly, the US became complacent towards this threat. Based on open-source literature, previous means to generate nuclear weapons proliferation intelligence has included environmental sampling, mining the open source literature, imagery intelligence, relying on national technical means (i.e. signals intelligence or SIGINT), nuclear trade-related information on exports, and relevant domestic political developments.[5] Many of these techniques encountered challenges due to terrain, targets being hard/denied access, export controlled materials acquired through third parties, and/or the US IC's SIGINT capabilities being redirected to other mission areas.[6] For the past 30 years and through today, nuclear intelligence assessments rely on characterization of a states' capabilities to enrich uranium through centrifuge technology.

Centrifugation seems to be a logical choice to evaluate nuclear weapons proliferation programs, as it offers the greatest efficiency amongst the known enrichment techniques and therefore is ubiquitously employed.[7] The US IC has subsequently invested incredible amounts of resources into looking for centrifuge technologies to assess nuclear weapons programs. This fixation on centrifugation, however, hinders fully understanding potential nuclear weapons proliferation activities within a particular state, especially if discretion is the focus of a particular state's enrichment activities. By not shifting strategies, the IC's approach to using centrifuges is akin to the drunk looking for their keys under the streetlamp—looking there simply because it is easier to see, despite losing their keys in the park across the street–effectively pigeonholing nuclear intelligence tactics under the Streetlight Effect.[8] Though it may seem easier, the IC's focus on centrifuges is not enough, especially given the gravity of incomplete intelligence.

The US IC must generate better nuclear weapons proliferation intelligence. Generating nuclear intelligence data needs to focus on characterizing the unknown activities of a state actor well before they arrive at a weapon. The aim of this paper is to propose a new way forward to generate nuclear weapons proliferation intelligence. Specifically, taking a holistic, problem-centered approach and coupling this with deliberate R&D will allow the US IC to generate new strategies for generating nuclear weapons proliferation intelligence. Two case studies involving the holistic approach applied to R&D will be presented to show how this can be utilized for nuclear weapons proliferation intelligence.

Background

In the development of nuclear weapons, centrifuges act as a very reliable method of enrichment. The more centrifuges a state operates, the faster they are able to enrich uranium and produce the special nuclear material needed for a weapon. Analyzing a state's centrifuge operation has historically been the standard way of assessing nuclear weapons proliferation activities, but this approach has limitations. Beginning with the first Gulf War, the US IC and international communities looked for centrifuges to assess the Iraqi nuclear weapons program and were surprised when they discovered the Iraqis using an alternative technique: electromagnetic isotope separation (EMIS).[9]

The most likely reason for this bias came from a 1982 report by Los Alamos National Laboratory (LANL) stating criterion for a state to pursue enrichment via EMIS. Based on this LANL report, the, and IC and the International Atomic Energy Agency (IAEA) assessed Iraq was not pursuing this method. Their assessment of the Iraqi nuclear weapons program leading up to the 1990 Gulf War was instead focused on the likelihood Iraq was using centrifuges.[10] Subsequent assessments of the Iraqi nuclear weapons program in the build-up to the 2003 Iraq War continued to focus on centrifuges. The US believed Iraq had an active nuclear weapons program based on purchases of a particular type of aluminum tub the US misattributed to centrifuge construction. This confirmation bias became the impetus for the Iraq War.[11]

Nearly 15 years later, centrifuges still remained the focus for characterizing a state's intentions, as evident in the 2015 Joint Comprehensive Plan of Action (JCPOA) a.k.a. the Iranian nuclear deal. In this UN agreement, the primary focus of the Iranian sanctions lies with the limitations placed on the type and quantity of centrifuges the Iranians were able to employ and the products from uranium enrichment.[12] In essence, the agreement sought to inhibit Iranian nuclear weapons development by placing restrictions on all things related to uranium enrichment via centrifuge technology. Despite the agreement, there were still considerable challenges in accurately assessing what was going on within Iran. This myopic focus on centrifuges contributes to the lack of intelligence extending to other state actors looking to proliferate nuclear weapons today.

A New Approach

How do we break free of the limitations of centrifugation, change our strategy, and reinvigorate the nuclear weapons proliferation intelligence capability of the US IC? How do we keep the intelligence focus as far to the left in the timeline of the actual detonation, in order to generate the most useful nuclear weapons proliferation intelligence? The author's stance is to take a holistic, problem-centered approach coupled with deliberate R&D in order to generate new strategies to overcome this lack of intelligence. From an investment and collaboration standpoint, the focus will be on Measurement and Signatures Intelligence (MASINT). MASINT can provide relatively shorter time-frames for development and operationalization of signatures to provide new strategies for nuclear weapons proliferation intelligence. In addition, MASINT can cost several orders of magnitude less than other signals intelligence and human intelligence, by utilizing existing intelligence media for collection. Finally, through the collaboration with other collection media, MASINT can help overcome the stovepipe problem the intelligence disciplines find themselves.[13]

Holistic approaches look at the complete system and not just components, taking into account both structure and ideas.[14] A problem-centered approach is rooted in education theory, as a way to promote critical thinking. Instead of providing strategies or answers, an open problem is presented to students and, through the course of learning a subject, students work towards a solution to that problem based on their evolving knowledge. A problem-centered approach allows for, and encourages, creative ways to approach open-ended problems.[15] When applied to the problem of nuclear weapons proliferation intelligence, this approach will help open the aperture for what we look for (apart from centrifugation) and allows the US IC to generate insight into the problem so they are no longer stuck under the streetlight. Using this problem-centered approach, deliberate R&D looks at both the nuclear weapon problem in its entirety *and* ensures the R&D can create an actionable strategy. The six-step Intelligence Process (IP) provides a framework to apply a holistic, problem-centered approach to focus R&D towards addressing an intelligence application.[16]

The Planning and Direction step, the very first step in the IP, calls for identifying and establishing the intelligence requirement. An analogous step can be created for specific R&D to uncover new intelligence strategies by asking the question: what can be used to generate a signal or signature for nuclear weapons proliferation? Specifically, is there some physical phenomenology related to nuclear weapons production, and does it create some sort of measureable signature? If there is a signature associated with it, is it unique and attributable to the question being asked? How does this propagate into the environment? Will this require significant long-term back-end assessments before it can produce useful intelligence for decision makers? The answers to these question feeds in to the next step of the intelligence cycle: collection

The Collection step asks what can be done to acquire the data to answer these questions, be it some electromagnetic, optical, or physical signature. Can the collection be performed with existing collection platforms? Can the collection occur via multiple techniques and still arrive at the same conclusion? The next step of the IP is to Process and Exploit the data acquired during

Collection. Processing and Exploitation describes the steps to translate raw data into useable, quantifiable data from which intelligence conclusions can be made. During Analysis and Production, the quantified data is translated into intelligence conclusions. The last step, Dissemination, communicates to customers and stakeholders the inferences generated from the intelligence cycle—are we able to communicate this capability to the right customer to expand the toolkit used to generate nuclear weapons proliferation intelligence?

The IP provides a framework for identifying deliberate R&D to address shortfalls in this process. Taking a holistic approach to this framework, i.e. looking at the multiple paths available to address the intelligence requirement provides insight to where R&D investments could be made to generate new strategies for nuclear weapons proliferation intelligence for the US IC. Figure 1 below for the R&D parallels created from the five steps within the intelligence process.

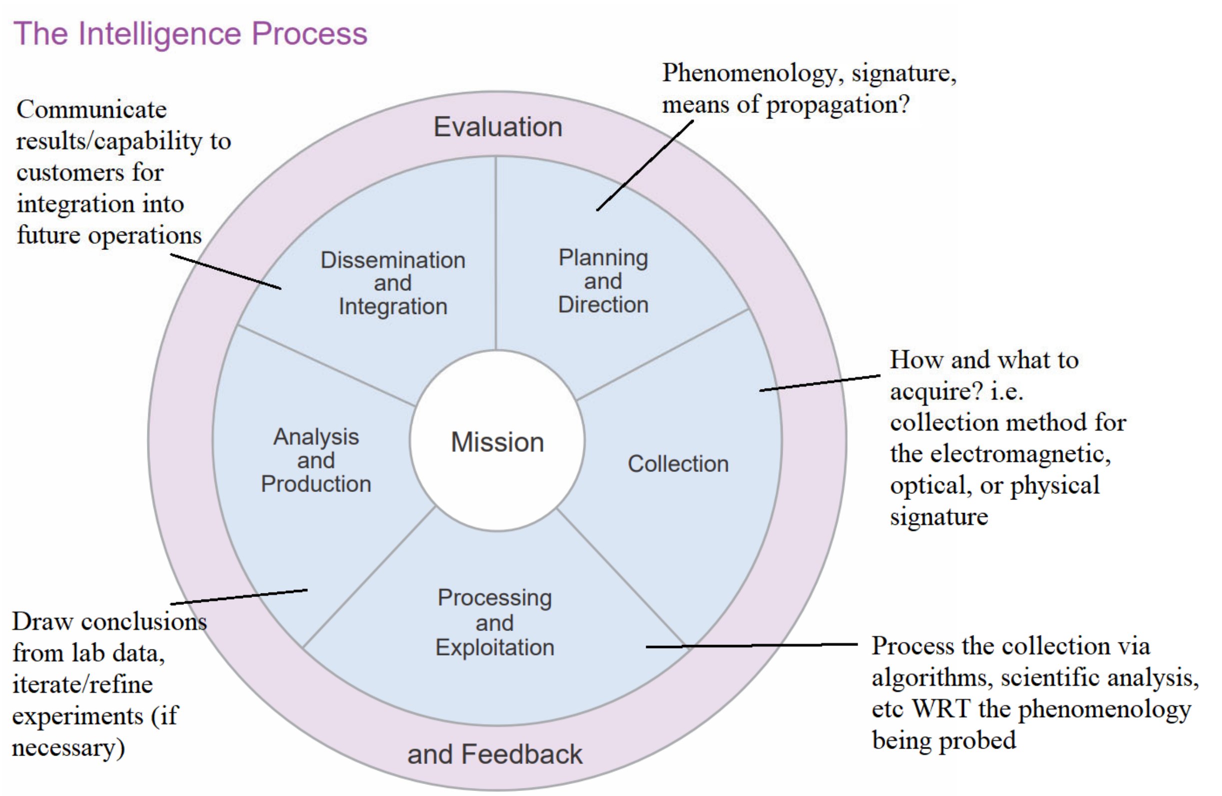

Figure 1 – R&D Analogs to the IP

Discussion

Applying a holistic approach to nuclear intelligence, we begin by defining the problem regarding nuclear weapons proliferation. Mere creation of the weapon itself is not the end-all concern when it comes to generating nuclear intelligence. There is still the incredible challenge for a state to deliver the payload to its intended target. For the purposes of exemplifying this process, Figure 2 below offers a simplified holistic look into a nuclear weapon and its sub-components limited to a missile delivery system, independent of the state actor being examined. Each sub-component offers an opportunity to breakdown how the nuclear weapon can evaluated for potential signatures for collection of nuclear intelligence. (Note, each step was not fully expounded due to the significant number of additional components each input could be broken into.)

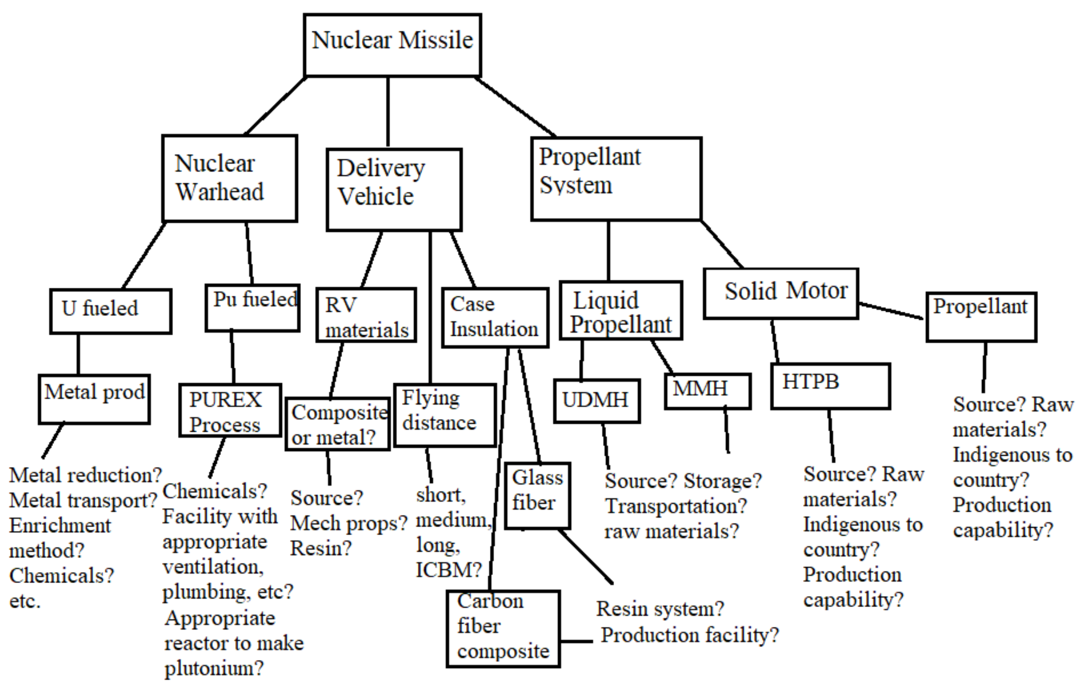

Figure 2 – Simplified holistic breakdown of a nuclear missile

Using Figure 2 as an example, the problem-centered approach begs the following questions: what are the key enabling technologies or processes, which can be inexplicably tied to nuclear missiles and provide significant insight into this threat? Additionally, are there inputs to the problem which show up in more than one area to generate economy of effort? Here is where the problem-centered approach gains its power—thinking backwards from the end-state to discover the key processes and technologies essential to making a nuclear missile a reality.

Case Studies

Two case studies applying the problem-centered approach are presented as examples for R&D's role in generating new nuclear weapons proliferation intelligence. The first stays in the familiar realm of looking at uranium enrichment via centrifuge technology. It also provides insight into the missile used for delivery and increased opportunities for gathering intelligence. The second case study widens the aperture of uranium enrichment beyond centrifuge technology in order to characterize potential weapons proliferation activities earlier in the process.

Case Study 1

The 2015 JCPOA placed restrictions on the Iranians from employing advanced centrifuges, in order to impede the speed which uranium could be enriched. However, the Iranians were allowed to maintain 1008 IR-2m and single numbers of the more advanced centrifuges, the IR-4, IR-6, and IR-8.[17] All of these advanced centrifuges contained carbon-fiber reinforced composite based components to replace the maraging steel traditionally used in centrifuges. The carbon fiber composite is ideal for two reasons. First, it allows for greater centrifugation speeds, which accelerates the timeframe needed to enrich uranium for a weapon.[18] Second, maraging steel is export controlled, and new centrifuges can be constructed without this supply chain shortfall. In the summer of 2020, their advanced centrifuge production facility was destroyed in a fire, and have since undertaken efforts to replace it.[19] Efforts to replace the centrifuge production facility begs the question what significance does centrifugation have in

Iran's ability to produce SNM—i.e. why did the Iranians rebuild the facility if they only need uranium for energy production?

Despite the restrictions from the JCPOA on the number of advanced centrifuges Iran is able to operate, construction of the facility is proceeding, and will require large quantities of carbon fiber. In addition to centrifuges, carbon fiber is a critical enabling material in the production of delivery-system components. Because of its strength-to-weight properties, incorporating carbon fiber into a delivery system increases the probability a weapon would have the range need to strike the US, its interests, or its allies. While Iran does have a native capability to manufacture carbon fibers, these fibers are not believed to have mechanical properties necessary to operate at the declared capabilities by the Iranians.[20] Are the Iranians using carbon fibers from an external manufacturer, and if so, in what capacity and by what means are they acquiring aerospace grade carbon fibers? These are export-controlled materials through the Nuclear Supplier's Group and have limited restriction through the Missile Technology Control Regime.[21] Here is where the holistic approach from the IP and deliberate R&D would be able to generate additional nuclear weapons proliferation intelligence for the IC.

It all begins by asking questions. Is there some sort of physical signature which can be used to characterize carbon fibers of the appropriate grade for use in aerospace applications and advanced centrifuges, to enable the capabilities the Iranians are currently lacking? From a scientific standpoint, can science and technology (S&T) personnel perform chemical or mechanical testing on carbon fibers to identify a specific manufacturing process of carbon fibers? In evaluating this generic signature, does it provide enough clarity to not be attributable to another manufacturer? Depending on the forensics evaluation being performed, is there a minimum amount of sample needed to perform the characterization? On the collection front, this presents a unique challenge, because this would require the carbon fiber to be in hand, which extends beyond the scope of applying R&D to generating nuclear weapons proliferation intelligence. If the US IC is able to acquire carbon fiber samples from those used by the Iranians (or any other nation being characterized for nuclear weapons proliferation intelligence), during the R&D processing and exploitation step, there must be an order to perform the carbon fiber chemical and mechanical property evaluation, in order to ensure the samples are not spoiled, cross-contaminated, and/or consumed prior to finishing the evaluation for quantifiable data. In the Analysis and Production phase, what are the conclusions to be drawn from the fiber samples? Can these materials be traced back to a specific grade of carbon fiber? Is there enough insight to determine what specific manufacturing plant made and sold the fiber and also provide insight into the supply chain used to acquire the fibers? Based on the R&D analysis, is there another method to perform subsequent collections, beyond having the physical fibers? Finally, in the dissemination step, how is this data communicated to rest of the IC? Does this translate to a new essential element of information (EEI) and an organization within the rest of the IC create a requirement based on carbon fiber analysis, due to the use in advanced centrifuges and delivery vehicles? Or if the fibers are in hand, how are the results of the analysis communicated to interested parties and end-users of the data? A process flow-diagram is provided below in Figure 3 as a visualization of this holistic R&D process for evaluating carbon fibers.

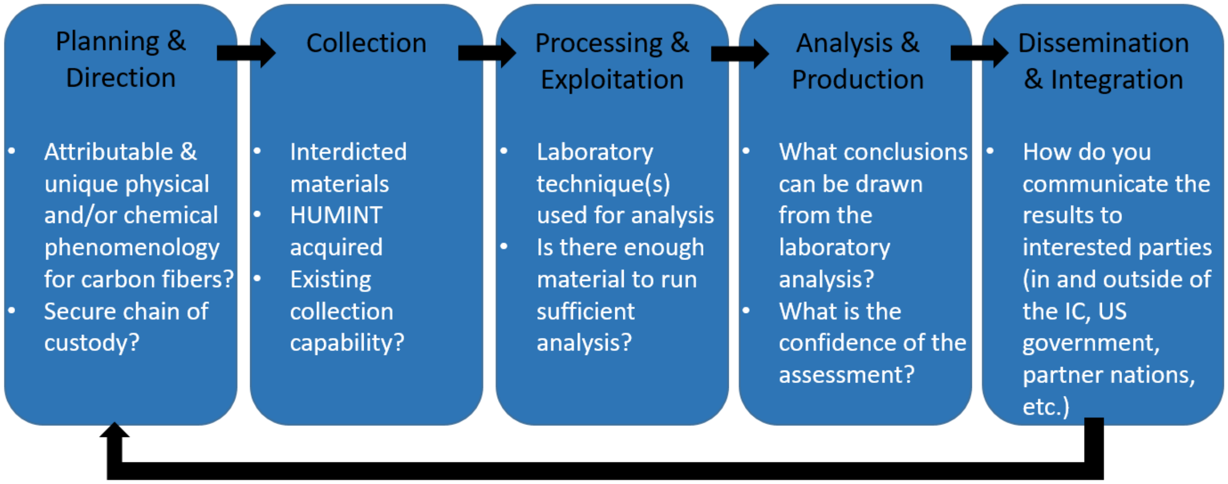

Figure 3 – Holistic R&D process applied to carbon fiber analysis

<u>Case Study 2</u>

There are six general methods used to enrich uranium, and five of these categories involve uranium hexafluoride (hex) as a feedstock material, with the one exception being EMIS.[22] What makes hex unique is the immense difficulty associated with its production. Fluorine gas is extremely reactive (i.e. it releases a lot of heat when undergoing a chemical reaction), caustic, and toxic. As a result, it requires unique and significant safeguards during handling in order to minimize the danger it presents to those working with it, to include careful monitoring of the piping used in industrial equipment associated hex production. Fluorine gas is stored under high-pressure when transported and used in industrial processes. However, due to the high reactivity, it is not reacted with the uranium under high pressure, because of concerns of over-pressurization (i.e. explosion) occurring with the reactor vessel used to produce hex. In order to mitigate the danger of a reaction proceeding too quickly, fluorine gas is introduced after a series of pressure "steps-downs." Keeping in mind the reactivity of the fluorine gas, it will react with and corrode the pipes and valves used to reduce the pressure prior to entering the reactor vessel to react with the uranium. The combination of the high-pressure gas and corrosion will weaken the structural integrity of the piping. In order to prevent a fluorination plant from shutting down due to an accident, these pipes and valves must be replaced at some periodicity, due to fluorine exposure. Based on open source literature, Iran wants to produce significant quantities of hex, which presents a unique opportunity to better characterize their potential nuclear weapons proliferation activities.[23] As a result, the metal coming in contact with the fluorine gas must undergo periodic replacement if the hex used for enrichment is produced at a level beyond what is publicly declared, both of which the Iranian regime is suspected. One final thing to note is the types of alloys used in the production of hex. Nickel-based alloys provide maximum safety, due to the low reactivity to fluorine gas. However, high-strength nickel alloys are export controlled materials, due to their importance to national security and potential for use in WMD production.[24] From an R&D standpoint this problem can be bound by exploring metal resistant to fluorine corrosion and a more reactive alloy to see the expected maintenance periodicity.

In applying the holistic approach from the IP model and coupling this with deliberate R&D, the following considerations are taken into account. What signature(s) can be used to characterize the corrosion and structural integrity of the piping to show when it necessitates replacement? Depending on the forensics evaluation being performed, is there a minimum amount of sample needed to perform the characterization? Similar to the carbon fiber scenario, this presents a challenge on the collection front because this also requires the piping used to be in hand, which extends beyond the scope of applying R&D to generating nuclear weapons proliferation intelligence. If the US IC is able to acquire piping samples used by the Iranians (or any other nation being characterized for nuclear weapons proliferation intelligence), during the R&D processing and exploitation step, there must be an order to perform the materials analysis, again, in order to ensure the samples are not spoiled, cross-contaminated, and/or consumed prior to finishing the evaluation for quantifiable data. Additionally, you run the potential of off-gassing trapped fluorine into the environment and/or laboratory equipment used during for analysis. Therefore, consideration must be paid to whether there is laboratory space capable of performing this dangerous analysis. In the Analysis and Production phase, what are the conclusions to be drawn from piping analysis? Is there a way to estimate the exposure conditions of the piping to fluorine gas to predict fluorine gas, and subsequent, hex throughput? Is the throughput estimate a reliable figure to quantify hex production? Can different manufacturing plant set-ups be differentiated from one another? Can the pipes exposed to the different pressure of fluorine gas be reliably differentiated from one another? From the R&D analysis, is there another method to perform subsequent collections, beyond having the physical piping? Finally, in the dissemination step, how is this data communicated to rest of the IC? Does this translate to a new EEI and an organization within the IC create a collection requirement against the piping? Just as the case for the fibers, how are the results of the analysis communicated to interested parties and end-users of the data? Figure 4 below shows the holistic R&D process applied to piping.

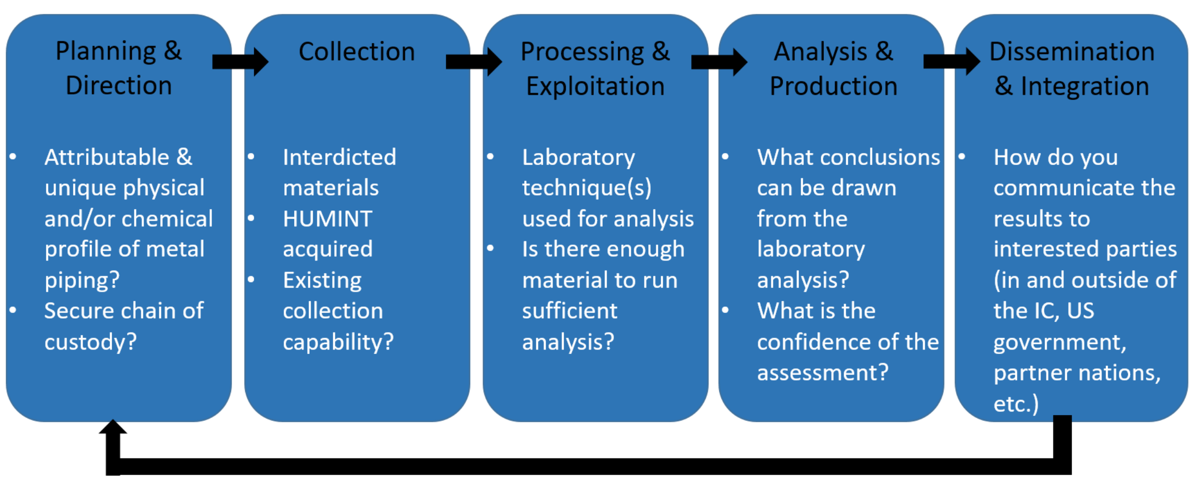

Figure 4 - Holistic R&D process applied to piping analysis

In both case studies, answering to the above questions will help identify where R&D investments should be made and how to prioritize efforts to create a new strategy for nuclear weapons proliferation intelligence.

Conclusion

The holistic, problem-centered approach, coupled with deliberate R&D provides new avenues to gather nuclear weapons manufacturing intelligence. It provides a framework of questions to ask, and steps to pursue, to assure the IC is focused on unique elements of the nuclear weapons proliferation problem. This methodology would replace the old focus on centrifugation, and allow for additional expansion into future intelligence arenas as technology advances and processes streamline, even if those advances get rid of centrifugation entirely. It is crucial the US IC remain open-minded and pursue these types of holistic approaches, not only to remain at the cutting edge of intelligence gathering, but ultimately to continue to protect the US and our allies by focusing as early as possible in the nuclear weapons proliferation cycle.

Endnotes

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