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LITERATURE SEARCH FOR CHEMICAL EXPOSURES IMPACTING HUMAN PERFORMANCE ATTRIBUTES: METHODS

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14. ABSTRACT

Using operational exposure data to predict decrements of Airman performance starts by understanding potential exposures, their impact on performance attributes, and the dose-response relationship between chemical concentration and percent decrement to the attribute. While it is well established that chemical exposures can negatively impact performance attributes such as alertness, there is no summary document focused on chemical exposures and performance attributes of interest to the Air Force. To close this gap, a systematic literature review will be conducted on 126 chemicals known to occur in Air Force occupational environments and their impact on four performance attribute categories: hearing, vision, psychology, and physiology. The chemical list was derived from chemicals used at representative Air Force bases and occupational exposure studies for the F-22 and a hardened aircraft shelter during F-35 engine runs. The scope of the review is broad enough to require automated processes to assist researchers in finding literature, screening papers for applicability, and extracting data for further analysis. Eight automation technologies were reviewed and one commercial software system was purchased. This literature review will be delivered iteratively by chemical class.

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TABLE OF CONTENT

LIST OF TABLES

Page

1.0 EXECUTIVE SUMMARY

Using operational exposure data to predict decrements of Airman Performance starts by understanding potential exposures, their impact on performance attributes, and the dose-response relationship between chemical concentration and percent decrement to the attribute. While it is well established that chemical exposures can negatively impact performance attributes such as alertness, there is no summary document focused on chemical exposures and performance attributes of interest to the Air Force.

To close this gap, a systematic literature review will be conducted on 126 chemicals known to occur in Air Force occupational environments and their impact on four performance attribute categories: hearing, vision, psychology, and physiology. The chemical list was derived from chemicals used at representative Air Force bases and occupational exposure studies for the F-22 and a hardened aircraft shelter during F-35 engine runs.

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2.0 INTRODUCTION

Mission success is predicated on the human weapon system operating at peak performance. Even small decrements in key attributes, like cognition, can impact mission outcomes (Amitai *et al.*, 1998; Chen *et al.*, 2009; Gatto *et al.*, 2014; Mohammed *et al.*, 2020). Operating environments for Airmen are complex, dynamic, and often unique among occupational exposures. Chemical exposures within these environments can contribute to decreased performance, but there is no single document detailing the potential for chemical exposure in an Air Force environment, the performance attribute impacted, and the dose-response relationship between chemical and level of impact. The synthesis of disparate datasets is needed to protect the Airman by predicting mission risks. This synthesis will be delivered as a systematic literature review of chemicals found in Air Force occupational environments and their impact on performance attributes of concern.

A systematic literature review is a comprehensive analysis of all available literature on a topic to make data-driven decisions (Higgins and Thomas, 2019). This process first came to prominence in the medical community as a way to determine the efficacy of different treatment methods. Other communities, including the National Toxicology Program (NTP) and the U.S. Environmental Protection Agency (EPA), have adopted this rigorous process for their own ends (EPA, 2018; NTP, 2019).

Regardless of discipline, systematic reviews are published using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) format (Moher *et al.*, 2009). Systematic reviews must document all decision points in their review, including where the literature was sourced (e.g. databases, grey literature, conference proceedings), the inclusion and exclusion

criteria for a paper, the number of papers included and excluded in each phase, and what meta-data were collected from each paper. It is common for researchers to screen thousands of abstracts during a single review which translates to hundreds of man-hours.

Despite its labor-intensive nature, the rigor the systematic literature review process adds when comparing patient outcomes or medical methods has made it the gold standard in the medical community. Many efforts are underway to automate portions of the review to allow researchers to focus their time on the synthesis and interpretation of the data available from all appropriate literature. The Exposure Health (EH) team considered several commercial and open-source software options as part of their systematic literature review of chemical impacts to physiological attributes of concern to the Airman. The software will be summarized as part of the results completed for this systematic literature review.

3.0 METHODS

A list of performance attributes was compiled by a team in the Force Health Protection Section of 711 HPW/RHBA (See Appendix A). The list was reviewed to determine the ones believed to be impacted by chemical exposure. All of the audiology attributes, eight of the physiology attributes, and eleven of the psychology attributes were chosen. For vision, eight of the eleven attributes were selected initially but when the combined list of search terms was compiled all of the vision attributes were covered by search terms. For physiology and psychology attributes, several additional search terms were added based on anatomy and physiology believed to be relevant for this effort. For all of the four attribute categories, relevant toxicity terms were added to help link chemical exposure to the performance attributes. Finally, a number of general exposure study terms were added along with the chemical name and the Chemical Abstracts Service registry number (CASRN or CAS#). The CASRN is the unique numerical identifier assigned by the Chemical Abstracts Service to every chemical substance described in the open literature since 1957. The complete list of search terms is shown below in **Table 1**. The list was then emailed to a reference librarian in the Air Force Research Labortory D'Azzo Research Library to begin a series of test searches to work out the optimum procedure to search each chemical of Air Force interest.

Table 1. Complete list of search terms chosen for attributes and chemicals of Air Force interest

Attribute Category	Search Terms
General terms for exposure studies	Chemical name and CAS# plus each of the following: exposure, inhalation, dermal/skin, oral/ingestion/gavage, toxicity, acute health effects, neurotox*. Then chemical name and CAS# plus each of the following terms in each of the four categories of attributes
Auditory	hearing, hearing loss, auditory, auditory threshold, auditory cutoff frequency, central auditory system, auditory temporal processing, auditory + temporal lobe, auditory cortex, word recognition + noise, sound localization, sentence recognition + noise, speech recognition + noise, spatial release from masking (SRM), tinnitus, vestibular, balance, auditory frequency shift, speech + differentiation, speech + recognition
Physiology	respiratory, respiration, respiratory rates, respiratory volume, motor activity, response to stimuli, body composition of fat/adipose, range of motion, extreme(s) of motion, functional movement, functional movement screen, mobility, flexor strength, grip strength, neuromuscular strength, core strength test, neuromuscular endurance, upper extremity steadiness, lower extremity steadiness, steadiness, dexterity, coordination, whole body agility, aerobic endurance, anaerobic performance capacity, chronotype
Psychology	behavior, neurobehavioral, neuroticism, cognition, cognitive function, activity level, motor activity, coordination, functional observational battery/FOB, neuropathologic, problem solving, mental ability, fear, anxiety, aggression, depression, CNS depression, acoustic startle, active avoidance, water maze, conditioned fear, force swim test, Morris water maze, inhibitory/passive avoidance, novel object recognition, light-dark box, rotor-rod, radial-arm water maze, social preference, Wisconsin Card Sorting Test (WCST), discrimination, prefrontal cortex, hippocampus, hippocampal, hallucination, risk-taking, mental focus, openness to experience, mental fatigue, OCEAN model, mental rotation, Verbal Intelligence, Performance Intelligence, working memory, N-back
Vision	vision, eye toxicity, eye irritation, ocular toxicity, achromatic contrast sensitivity, chromatic color contrast sensitivity, visual acuity, depth perception, binocular fusion range, field of view, blindness

The list of chemicals chosen for this review is comprised of the highest priority chemicals used across the Air Force by mass and by chemicals identified in Air Force specific exposure assessments. There were three primary sources used to identify chemicals that fit this profile.

The first source was the chemical inventories pulled from the Air Force's Enterprise Environmental, Safety, and Occupational Health Management Information System (EESOH-MIS). For each Major Command (MAJCOM), a representative base was identified (See **Table 2**). An EESOH-MIS expert generated a 2020 chemical inventory report for each base. Within the reports, the chemical name, CAS, industrial process, and quantity used per operation were captured. For each base, the top 100 chemicals consumed in 2020 by mass were considered for inclusion in the final list.

Table 2. Representative Air Force Base (AFB) by Major Commands

MAJCOM	**Representative Base**
Air Combat Command (ACC)	Nellis AFB
Air Education and Training Command (AETC)	Joint Base San Antonio
Air Force District of Washington (AFDW)	Joint Base Andrews
Air Force Materiel Command (AFMC)	Wright-Patterson AFB
Air Force Global Strike Command (AFGSC)	Minot AFB
Air Mobility Command (AMC)	Joint Base McGuire-Dix-Lakehurst
Air Force Special Operations Command (AFSOC)	Cannon AFB
Pacific Air Forces (PACAF)	Kadena AB
United States Air Forces Europe/Africa (USAFE)/(AFRICOM)	Ramstein AB
United States Space Force (USSF)	Vandenberg AFB

The second source was a list of chemicals identified in a hardened aircraft shelter (HAS) during engine runs of an F-35 (McKinley et al., 2016). These chemicals were unique in that they represented combustion by-products and therefore were unlikely to appear in any chemical inventory found in EESOH-MIS. All 76 chemicals discovered during the HAS study were included in the final list.

The third source was a list of chemicals identified during sampling of cockpit air in an F-22. This list numbered over 300 chemicals, so a subset of those chemicals that overlapped with the HAS list or two or more Air Force bases were selected for further review.

When first compiling the top 100 chemicals at each base, the HAS list, and the F-22 chemical list, 882 unique chemicals were present. Researchers used a combination of anticipated severity of health effects due to exposure, frequency of occurrence across bases, and estimated the potential for exposure to winnow the list down.

Within the bioenvironmental engineering (BE) career field, the consulting branch, OEC, developed a chemical hazard evaluation tool (CHET), in which 2279 chemicals were assigned

health effect ratings (HER) for exposure via inhalation, dermal contact, and ingestion. For those chemicals on the list of 800+ that also appeared in the CHET, the health effect ratings for the three exposure routes were copied over. For those chemicals which did not appear in the CHET, health effects reported in the literature were copied from haz-map.com.

In the first pass, 178 chemicals were removed from the list of 882 since they did not appear on the HAS list and were only reported as being used at one base. The second pass removed 24 chemicals that were not on the HAS list and had a combined HER rating across the three exposure routes of ≤2. Forty-seven additional chemicals were removed for only appearing on two bases and not on the HAS list. Twenty-one chemicals were combined into a single, representative CAS based on all 21 chemicals having a product description of petroleum distillates. Finally, four chemicals did not appear on the HAS list and were reported as having minimal health effects by haz-map.com. In total, 273 chemicals were removed from further consideration.

All 76 chemicals appearing on the HAS list were included for the reasons mentioned above. Once HAS chemicals were removed from consideration, the remaining list of 533 chemicals was sorted by the number of bases reporting their use. The top 40 chemicals used across bases were captured and added to the final list.

116 chemicals were identified for further review. This list was sent out to other researchers within RH for review. Suggestions were made to include chemicals on the OSHA expanded standard list, of which five chemicals were selected. Trimethylsilanol is of interest among Navy IHs due to its presence during pilot breathing air studies, so it was added to the list. 1-Decene dimer, a known component in polyalphaolefin (PAO) coolant, did not initially make the round of cuts based on its reported frequency of use, but was re-added as it has been identified as an Air Force chemical of concern. Respirable particles and elemental carbon were added as they are aerosols with documented health effects and known to occur as a byproduct of combustion. Finally, PIP 3.1 oil, was added on the recommendation of a team member. In total, 126 chemicals were chosen for the final review.

Given the number of chemicals and performance attributes to review, researchers investigated ways of automating portions of the systematic literature review process. As part of the review process, open-source and commercial products were first identified through peer-reviewed literature and evaluated for ease of use, automation potential, and applicability (Clark et al., 2020; Harrison et al., 2020; Ouzzani et al., 2016). When appropriate, researchers attended product demonstrations and downloaded software for trial periods.

4.0 RESULTS

Appendix B shows the current list of chemicals chosen for the literature along with meta-data: major and minor chemical class, HER for inhalation, dermal, and ingestion, what data source the chemical came from, how frequently the chemical appeared across all MAJCOMs, the Air Force process that uses it and the shops where the processes take place.

Searching for articles, screening abstracts, and meta-analysis were three areas identified as having the most potential for saving researcher hours through automation. The eight products evaluated are described below, grouped by focus area.

Systematic Literature Review Software

Literature search tools

Mining Enriched Literature Objects to Derive Intermediates (**MELODI**) is a freely available data mining tool developed by the Bristol Medical School at the University of Bristol (http://melodi.biocompute.org.uk). The literature mining platform can be used to examine the relationship between two biomedical concepts such as risk factors and health outcomes or chemicals and attributes. Using PubMed's Medical Subject Headings (MeSH) terms and subject-predicate-object triples from the Semantic Medline Database (SemMedDB), MELODI can find MEDLINE articles with overlapping elements of the two biomedical concepts.

MELODI is comprehensive in its literature mining by including low-impact papers that might have been overlooked by other literature search programs. MELODI could be useful to potentially find these relevant papers. However, the program is not efficient in that it does not allow for multiple exposures and outcomes to be run concurrently and can take a long time to complete a query. In addition, it was also determined that the concepts used for the search need to be broad to have significant results.

Sematrix is a commercial literature search tool developed by Battelle (https://www.battelle.org). To review this tool, the team met with a Battelle software engineer to discuss their software and meta-analysis and systematic review capabilities. Sematrix searches articles at the sentence level using subject-predicate-object as search terms, rather than keywords, to extract data and provides a higher efficiency to find articles for a literature search. Unfortunately, their software is still being developed and the features needed for this project are not yet available. Battelle will inform us when the next phase of their development is complete.

QInsight is a commercial literature search tool optimized for biological studies developed by Quertle (https://quertle.com/products/). An Artificial Intelligence (AI) function queries the collected literature using open-ended questions to find relationships between the subject matter and possible effects, such as a relationship between heart disease and carbon black. The cost of a single license is high for a small research team working on a review but may be appropriate as a tool for libraries to maintain for their reference librarians.

PaperBot.io is an open-source software developed by Maraver *et al.* (2019) to assist in searching for papers to include in a literature review (http://PaperBot.io). The web-crawler autonomously searches databases for pertinent papers and indexes the bibliographic information for researchers to review. The software currently requires users to have moderate programming knowledge and it has not yet been packaged for use as part of a commercial program.

Abstract Screening Tools

Rayyan is an open-source, web-based abstract screening tool developed by the Qatar Computing Research Institute (https://rayyan.qcri.org). The platform uses a machine-learning algorithm that

learns as the researcher classifies articles as relevant or irrelevant to the study aims. Within a few hundred abstracts, the AI provides a 6-star ranking to indicate the likelihood that the researcher will want to keep the paper for full-paper screening. The program allows for blind reviews so that two researchers can classify an article without the other's decision biasing theirs. In the event, a dispute between exclusion or inclusion of the abstract occurs, Rayyan has an option for a third reviewer to act as a tie-breaker. After the screening process, the selected references can be exported in a variety of reference formats for import into reference systems like EndNote.

Rayyan has a deduplication feature to assist researchers in removing duplicate articles collected by querying multiple databases. The AI can accurately find duplicated articles and flag them for reviewers, even giving a percent likelihood of duplication when the same material was covered in different journal articles; however, deduplication must be re-run after adding new data to the program and all decisions must be made again. This increases time spent in the program and limits the ability of researchers to continue adding from databases incrementally.

Meta-data Analysis Tools

Review Manager (**RevMan**) v5.3 is the Cochrane Collaboration's software for preparing and maintaining Cochrane reviews (https://training.cochrane.org/online-learning/core-software-cochrane-reviews/revman). The software facilitates the preparation of full reviews, including text, characteristics of studies, comparison tables, and study data. It can perform a meta-analysis of data and present the results graphically. This requires the user to correctly extract the data to be analyzed from the selected studies. It's ideally used for writing reviews of studies of the effects of healthcare interventions and diagnostic test accuracy, but reviews of methodology studies and overviews of reviews can be written with the software as well. The Department of Veterans Affairs has used RevMan for writing and accessing other medical reviews since 2008.

The first step in its implementation is defining the review question by specifying the population of participants, types of interventions and comparisons, and types of outcomes that are of interest. These components, with the additional specification of types of study that will be included, form the basis of the pre-specified eligibility criteria for studies selected using the software. The Cochrane Collaboration uses the Archie Server as their central server for managing all of the reviews performed and their associated documents and contact details. The web-based software is installation-free and automatically updates. Given the broad scope of this literature review to assess the potential impact on numerous human performance attributes by some 100+ chemicals, Revman was not suitable. However, our team identified Revman as an attractive systematic literature review tool for performing meta-analyses on focused research questions that may arise from this study.

Comprehensive Systematic Literature Review Programs

Covidence is a commercial software designed to help researchers collaborate when conducting a systematic literature review (https://www.covidence.org). The software allows multiple users to upload references, screen titles, and abstracts, further screen full papers, create forms to extract meta-data, and conduct bias analyses of the studies included. Forms for extracting meta-data can be user-customized and ensure all researchers reviewing papers pull data consistently.

Covidence does not use machine learning or AI algorithms to assist researchers in abstract screening, so there is are no efficiency gains from using the software for screening. Meta-data extraction and bias analysis are manually conducted. For smaller projects, this software streamlines collaboration and keeps track of details required to be reported in a systematic review, such as the number of studies reviewed, the number of studies included, the inclusion/exclusion criteria, etc.

DistillerSR is a commercial software designed for groups of researchers conducting large literature reviews (https://www.evidence partners.com). The process includes stages to 1) search, 2) screen, 3) retrieve full texts, 4) extract meta-data, and 5) generate reports. DistillerSR allows alerts to be set up with databases so that when a new paper on the topic of interest is published, it is automatically added to the project file. Within the project, a deduplicating AI searches all the papers and removes duplicates. During screening, DistillerSR's AI learns as researchers include or exclude articles. The AI reorders the list of abstracts to move those most likely to be included to the top. As abstracts are screened, researchers can see the AI's predictions for what percent of the articles remaining are likely to be included.

DistillerSR has an optional second AI package called Daisy that can extract data by answering closed questions, such as, "Is this study using animal, human, or in vitro models?". Daisy learns as researchers answer these closed questions, and once sufficient confidence in Daisy's responses is reached, the program can autonomously answer questions for the remaining articles. To reach the point of confidence, experts at Evidence Partners conduct a one-day training session with researchers and their specific datasets to set up the questions and demonstrate how to verify Daisy has been fully trained for the desired results. Data extraction for open questions, from figures, or statistics in the studies must be done manually. To aid in this manual extraction, fillable forms are created by the researchers so that all who are reviewing papers capture the same type of data.

5.0 DISCUSSION

The list of chemicals selected for the literature review was derived from the following bioenvironmental engineering inventories: 1) EESOH-MIS 2020 inventories from a representative base within each MAJCOM, 2) a list of chemicals identified in a HAS during an engine runs of an F-35 (McKinley *et al.*, 2016), and 3) a list of chemicals identified during sampling of cockpit air in an F-22, which overlapped with the HAS list. These inventories resulted in 882 unique chemicals. The list was then narrowed down based upon the anticipated severity of health effects due to exposure (based upon HER ratings), the frequency of the chemicals' occurrence across bases, and confirmations of potential for exposure. Lastly, the list was reviewed by RH researchers to ensure any chemicals of special interest were either added or not deleted. In total, 126 chemicals were chosen for the final review. Search terms were selected to reflect potential impacts on human performance attributes, including general toxicity terms. Once all full papers are screened and meta-data are extracted, several reports can be generated using DistillerSR's report repository. Among those report templates are several that generate flow diagrams needed for PRISMA publications.

6.0 CONCLUSIONS

For this literature review, AI capabilities are needed to complete the analyses of thousands of articles within a reasonable time frame. At this time, the open-source software reviewed did not include these capabilities, necessitating a commercial license. DistillerSR and its AI feature, Daisy, was selected because it eliminates duplicates and performs both a means of systematically selecting articles and mining qualitative and quantitative data from our literature searches, based upon criteria specified by the review team. Because Daisy trains on multiple-choice questions, a list of selection criteria questions was established by team members as well as a Risk of Bias checklist, based on Downs and Black (1998). The Risk of Bias checklist reduces judgment bias for individual elements from the selection, experiment/trial, performance, reporting, and other domains within each study. Another benefit of using DistillerSR is that Evidence Partners not only provides multiple training sessions to ensure the selection criteria are robust and on target, as well as assists whenever needed. This will expedite the extraction of qualitative and quantitative information.

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APPENDIX A: List of Air Force Performance Attributes by Category

Audiology (9) 9%	
BPR Name/Foundation	**Definition**
Auditory Threshold	The sound level below which a person is unable to detect any sound. For adults, 0 dB is the reference level. Both ears unless separate thresholds given for better ear (BE) or poorer ear (PE). Some test protocols require both ears to pass; other require only one.
Auditory Cutoff Frequency	Measurement of the highest frequency a person can detect when presented at a fixed 80 dB level.
Auditory structural Integrity	Cochlear function or mechanical interactions in the outer hair cells and basilar membrane. Health of the inner ear.
Auditory Temporal Processing	The ability of the central auditory system to process temporal information.
Word recognition in noise	The ability to understand speech in noisy environments.
Sound Localization	Ability to determine the location of a sound source, sometimes as a function of level or duration.
Sentence recognition	The ability to hear, process and repeat military relevant sentences heard.
Operational Speech in Speech Recognition	The ability to correctly identify and respond to speech in the presence of competing speech in the background.
Release of Spatial Masking	The ability to utilize auditory cues to aid with sound detection or speech understanding in noise.

Physiology (36) 36%	
BPR Name/Foundation	**Definition**
Body Composition Appropriateness	The result of the Jackson and Pollock skinfold caliper subcutaneous fat measurement equation based on gender.
Right (R.) Shoulder Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
R. Shoulder Abductor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
R. Elbow Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
R. Elbow Wrist Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
Left (L.) Shoulder Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.

Physiology (36) 36%	
BPR Name/Foundation	**Definition**
L. Shoulder Abductor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
L. Elbow Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
L. Wrist Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
R. Hip Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
R. Hip Extensor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
R. Knee Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
R. Ankle Dorsiflexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
L. Hip Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
L. Hip Extensor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
L. Knee Flexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
L. Ankle Dorsiflexor Extreme of Motion	For passive motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
Functional Movement Screen	An evaluative tool used to assess function, stability, and movement quality in subjects.
Bilateral Shoulder Extreme of Motion – Posture 1	For active motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.
Bilateral Shoulder Extreme of Motion – Posture 2	For active motion about a joint in the direction that the identified system would produce actively, the maximum rotation angle achievable relative to a defined reference.

Physiology (36) 36%	
BPR Name/Foundation	**Definition**
Anterior-Posterior Whole- body Mobility	The capacity for static and dynamic body control stressing postures in the A-P plane, requiring the combination of joint flexibility (extremes of motion), strength, stability, and coordination. Derived from the in-line lunge component of the Functional Movement Screen.
R. Shoulder Flexor Strength	The maximum torque the R. Shoulder Flexor can produce isometrically at a specified joint angle.
R. Hand Grip Strength	The maximum force the R. Hand can produce isometrically using a gripping posture.
L. Hand Grip Strength	The maximum force the L. Hand can produce isometrically using a gripping posture.
Lower Body Neuromuscular Strength	The maximal force of bilateral multi-joint movement produced isometrically using a modified deadlift posture.
Core strength test	The maximum number of Air Force approved sit-ups completed in one minute.
Upper Body Neuromuscular Endurance	The maximal force of upper body multi-joint movement produced during a 5-repitition max bench press.
R. Upper Extremity (UE) Steadiness (Static)	The inverse of the amount of motion produced at the hand in an outstretched R. arm (90 deg shoulder flexion, 0 degree abduction, 0 degree pronation) while attempting to produce zero motion.
L. UE Steadiness (Static)	The inverse of the amount of motion produced at the hand in an outstretched R. arm (90 deg shoulder flexion, 0 degree abduction, 0 degree pronation) while attempting to produce zero motion.
R. UE Dexterity	The capacity to execute controlled upper extremity motions using fingers of the R. hand to manipulate small objects (pegs) rapidly and accurately.
L. UE Dexterity	The capacity to execute controlled upper extremity motions using fingers of the L. hand to manipulate small objects (pegs) rapidly and accurately.
UE Coordination	The capacity to toss a tennis ball against the wall with one hand in an underarm action and catch the ball with the opposite hand in a rapid and accurate manner over one minute.
Whole Body Agility	The amount of time taken to traverse a 5-10-5 yard shuttle with three changes in direction.
Whole Body Explosive Power	Measured in inches, the power used to jump from a fixed position.
Aerobic Endurance	The capacity to sustain medium to high intensity physical exercise for extended periods of time through continual acquisition of oxygen.
Anaerobic Performance Capacity	The capacity to complete intense short or relatively long bursts of supramaximal exercise.
Chronotype	Peak time of alertness based on circadian rhythm.

Psychology (44) 44%	
BPR Name/Foundation	**Definition**
Neuroticism	Tendency to experience negative effects such as fear, sadness, embarrassment, anger, guilt, and disgust; prone to irrational ideas, are less able to control their impulses, and tend to cope poorly with stress.
Anxiety	Tendency to be apprehensive, fearful, prone to worry, nervous, tense, and jittery; may have specific fears or phobias, as well as free-floating anxiety; dwell on things that might go wrong.
Hostility	Tendency to experience anger and related states such as frustration and bitterness; readiness to experience anger.
Depression	Tendency to experience depressive affect; prone to feelings of guilt, sadness, hopelessness, and loneliness; easily discouraged and often dejected.
Self-Consciousness	Tendency to feel shame and embarrassment; uncomfortable around others, sensitive to ridicule, and prone to feelings of inferiority; akin to shyness and social anxiety; disturbed by awkward social situations.
Impulsiveness	Tendency to be unable to control cravings and urges; desires are perceived as too strong to resist.
Vulnerability	Tendency to feel unable to cope with stress, becoming dependent, hopeless, or panicked when facing emergency situations; incapable of handling themselves in difficult situations.
Extraversion	Tendency to be sociable; like people and prefer large groups and gatherings; assertive, active, and talkative; like excitement and stimulation and tend to be cheerful in disposition; upbeat, energetic, and optimistic.
Warmth	Tendency to be affectionate and friendly; genuinely like people and easily form close attachments to others.
Gregariousness	Tendency to enjoy the company of others and seek out social stimulation.
Assertiveness	Tendency to be dominant, forceful, and socially ascendant; speak without hesitation and often become group leaders.
Activity	Tendency towards rapid tempo and vigorous movement, a sense of energy, and a need to keep busy; lead fast-paced lives.
Excitement-Seeking	Tendency to crave excitement and stimulation; enjoy bright colors and noisy environments; akin to some aspects of sensation seeking.
Positive Emotions	Tendency to experience positive emotions such as joy, happiness, love, and excitement; laugh easily and often; cheerful and optimistic.

Psychology (44) 44%	
BPR Name/Foundation	**Definition**
Openness to Experience	Tendency to have an active imagination, aesthetic sensitivity, attentiveness to inner feelings, preference for variety, intellectual curiosity, and independence of judgment; curious about both inner and outer worlds; willing to entertain novel ideas and unconventional values; experience both positive and negative emotions more keenly than do closed individuals; willing to question authority and prepared to entertain new ethical, social, and political ideas.
Fantasy	Tendency to have a vivid imagination and an active fantasy life; daydream as a way of creating an interesting inner world for themselves; elaborate and develop their fantasies and believe that imagination contributes to a rich and creative life.
Aesthetics	Tendency to have a deep appreciation for art and beauty (e.g., poetry, music, art); need not have artistic talent.
Feelings	Tendency to be receptive to one's own inner feelings and emotions and the evaluation of emotion as an important part of life; experience deeper and more differentiated emotional states and feel both happiness and unhappiness more keenly than others do.
Actions	Tendency to be willing to try different activities, go to new places, or eat unusual foods; prefer novelty and variety to familiarity and routine.
Ideas	Tendency to demonstrate intellectual curiosity; open-mindedness and a willingness to consider new, perhaps unconventional, ideas; enjoy philosophical arguments and puzzles; does not necessarily imply high intelligence.
Values	Tendency to reexamine social, political, and religious values; question authority and tradition; generally liberal, regardless of political party affiliation; opposite of dogmatism.
Agreeableness	Tendency to be fundamentally altruistic; sympathetic to others and eager to help; believe that others will be equally helpful in return.
Trust	Tendency to believe that others are honest and well-intentioned; not cynical or skeptical.
Modesty	Tendency to be humble and self-effacing, though not necessarily lacking in self-confidence or self-esteem.
Compliance	Tendency to defer to others, to inhibit aggression, and to forgive and forget; meek and mild; cooperative, not competitive.
Altruism	Tendency to have an active concern for others' welfare as shown in generosity, consideration of others, and a willingness to assist others in need of help.

Psychology (44) 44%	
BPR Name/Foundation	**Definition**
Straightforwardness	Tendency to be frank, sincere, and ingenuous; not willing to manipulate others through flattery, craftiness, or deception.
Tender-Mindedness	Tendency to be sympathetic and concerned for others; moved by others' needs and emphasize the human side of social policies.
Conscientiousness	Tendency to be purposeful, strong-willed, and determined; typically involved in planning, organizing, and carrying out tasks; scrupulous, punctual, and reliable. High conscientiousness is associated with academic and occupational achievement.
Competence	Tendency to feel capable, sensible, prudent, and effective; to feel well-prepared to deal with life.
Self-Discipline	Tendency to begin tasks and carry them through to completion, despite boredom or other distractions; can motivate themselves to get the job done; does not procrastinate; not easily discouraged or eager to quit.
Achievement-Striving	Tendency to have high aspiration levels and work hard to achieve their goals; diligent and purposeful; ambitious and driven to succeed; have a sense of direction in life but may invest too much in their careers and become workaholics.
Dutifulness	Tendency to adhere strictly to ethical principles and scrupulously fulfill moral obligations; dependable and reliable.
Order	Tendency to be neat, tidy, and well-organized; prefer keep things in their proper places; methodical.
Deliberation	Tendency to think carefully before acting; cautious and deliberate; planful, not spontaneous.
General Mental Ability (g)	General capacity reflecting the covariation among scores on mental ability tests; variably defined.
Verbal Intelligence	Capacity for verbal reasoning and attention to verbal materials; includes aspects of acquired knowledge (e.g., mathematics, vocabulary).
Performance Intelligence	Capacity for fluid reasoning, spatial processing, attentiveness to details, and visual-motor integration.
Social Intelligence	Ability to evaluate social behavior, to identify behavior that is more socially desirable, and to give the reasons why certain laws and social customs are practiced.
Arithmetic Reasoning	Ability to solve numerical problems: reflects reasoning and problem-solving abilities.
General Domain Knowledge	Degree to which an individual has accumulated a fund of knowledge about diverse topics.

Psychology (44) 44%	
BPR Name/Foundation	**Definition**
Vocabulary	Number of words or verbal concepts that have been learned and stored; indicates the individual's openness to new information and concepts and reflects the capacity effectively to store, categorize, and retrieve this information appropriately.
Mental Rotation	Ability to visualize abstract visual objects in different positions in two-dimensional space and to be sensitive to critical differences among alternatives.
Information Ordering	The ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules (e.g., patterns of numbers, letters, words, pictures, mathematical operations).

Vision (11) 11%	
BPR Name/Foundation	**Definition**
Contrast sensitivity - achromatic - 1.25-arcmin gap	Contrast sensitivity for features having a specified spatial frequency and retinal illuminance.
Contrast sensitivity - achromatic - 2.5-arcmin gap	Contrast sensitivity for features having a specified spatial frequency and retinal illuminance.
Contrast sensitivity - achromatic - 16.7-arcmin gap	Contrast sensitivity for features having a specified spatial frequency and retinal illuminance.
Visual acuity – far	See details at a distance.
Contrast sensitivity - LWS cones - 16.7 arcmin gap	Match or detect differences between colors, including shades of color and brightness.
Contrast sensitivity - MWS cones - 16.7 arcmin gap	Match or detect differences between colors, including shades of color and brightness.
Contrast sensitivity - SWS cones - 16.7 arcmin gap	Match or detect differences between colors, including shades of color and brightness.
Depth perception - static - near	Judge which of several objects is closer or farther away from you, or judge the distance between you and an object.
Binocular fusion range - horizontal	Horizontal range over which a viewer can fuse stereoscopic images presented at a fixed focus distance.
Binocular fusion range - vertical	Vertical range over which a viewer can fuse stereoscopic images presented at a fixed focus distance.
Useful field of view	See objects or movement of objects to one's side when the eyes are looking ahead.

APPENDIX B. List of Chemicals Included in the Literature Review

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
67-64-1	ACETONE	Solvents	Ketones (<C12)	5	3		1	1	12
108-88-3	TOLUENE	Solvents	Aromatic Solvents	5	2		1	1	12
124-38-9	CARBON DIOXIDE	Toxic Gases & Vapors	Simple Asphyxiants	3	1	0	1	1	11
67-56-1	METHANOL, METHYL ALCOHOL	Solvents	Alcohols (<C12)	5	4		1	1	11
1330-20-7	**XYLENE (m-xylene: 108-38-3; o-xylene: 95-47-6; p-xylene: 106-42-3)	Solvents	Aromatic Solvents	3	3	0	1	0	11
67-63-0	ISOPROPANOL (IPA), 2-PROPANOL, 2 HYDROXYPROPANE	Solvents	Alcohols (<C12)	3	1		1	0	11
78-93-3	METHYL ETHYL KETONE, (MEK), 2- BUTANONE	Solvents	Ketones (<C12)	4	3		1	0	11
64-17-5	ETHANOL, ETHYL ALCOHOL	Solvents	Alcohols (<C12)	5	3		1	0	11
74-98-6	C3 as Propane	Toxic Gases & Vapors	Simple Asphyxiants	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	10
107-21-1	ETHYLENE GLYCOL	Other Classes	Ethylene Glycols	4	1		0	0	10
13463-67-7	TITANIUM DIOXIDE	Metals	Metals, Inorganic Compounds	5	3	1	0	0	10

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
25068-38-6	BISPHENOL A EPICHLOROHYDRIN POLYMER	Plastics & Rubber	Epoxy Resins	1	3	1	0	0	10
123-86-4	N-BUTYL ACETATE	Solvents	Esters (<C12)	3	1		1	0	9
112-34-5	DIETHYLENE GLYCOL MONOBUTYL ETHER; 2-(2-BUTOXYETHOXY)-ETHANOL	Solvents	Glycol Ethers (E Series)	4	3	0	0	0	9
111-46-6	DIETHYLENE GLYCOL	Other Classes	Ethylene Glycols	5	3	0	0	0	9
1330-78-5	TRICRESYL PHOSPHATE (MIXED ISOMERS)	Other Classes	Organophosphates, Other	4	3	3	1	0	8
110-43-0	HEPTAN-2-ONE METHYL N-AMYL KETONE, 2-HEPTANONE	Solvents	Ketones (<C12)	3	1	0	1	0	8
7439-92-1	LEAD	Metals	Lead Compounds, Inorganic	5	3	3	0	0	8
7664-93-9	SULFURIC ACID	Toxic Gases & Vapors	Acids, Inorganic	5	3		0	0	8
28182-81-2	POLYMERIC HEXAMETHYLENE DIISOCYANATE, HEXANE, 1,6-DIISOCYANATO-, HOMOPOLYMER	Plastics & Rubber	Polymers	4	3	1	0	0	8

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
64742-94-5	HEAVY AROMATIC SOLVENT NAPHTHA (PETROLEUM)	Other Classes	Petroleum Distillates, Other	5	4	0	0	0	8
1310-73-2	SODIUM HYDROXIDE, CAUSTIC SODA, LYE	Other Classes	Bases	5	3		0	0	8
111-76-2	BUTYL CELLOSOLVE, ETHYLENE GLYCOL MONO-N-BUTYL ETHER, 2-BUTOXYETHANOL	Solvents	Glycol Ethers (E Series)	5	4		1	0	7
79-20-9	METHYL ACETATE	Solvents	Esters (<C12)	3	1		1	0	7
1313-13-9	MANGANESE DIOXIDE	Metals	Manganese Compounds, Inorganic	5	1	3	0	0	7
#N/A	ASPHALT	Other Classes	Polycyclic Aromatic Hydrocarbons	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	0	7
127087-87-0	POLYETHYLENE GLYCOL MONO (BRANCHED P-NONYLPHENYL) ETHER	Other Classes	Emulsifiers/Surfactants	3	2		0	0	7
7727-43-7	BARIUM SULFATE	Metals	Metals, Inorganic Compounds	4	1	3	0	0	7
74-86-2	ACETYLENE	Toxic Gases & Vapors	Simple Asphyxiants	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	6

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
100-41-4	ETHYL BENZENE	Solvents	Aromatic Solvents	5	1		1	1	6
108-10-1	METHYL ISOBUTYL KETONE, (MIBK), 4-METHYLPENTAN-2-ONE	Solvents	Ketones (<C12)	5	1		1	0	6
115-10-6	DIMETHYL ETHER	Solvents	Ethers (<C12)	3	1	0	1	0	6
106-97-8	BUTANE	Solvents	Aliphatics, Saturated (<C12)	3	1	0	1	0	6
7439-89-6	IRON	Metals	Elements, Metallic	3	0	2	0	0	6
90-30-2	1-NAPHTHALENAMINE, N-PHENYL-	Nitrogen Compounds	Naphthylamines	1	3	0	0	0	6
142-82-5	HEPTANE	Solvents	Aliphatics, Saturated (<C12)	4	3	0	1	1	5
8052-41-3	STODDARD SOLVENT	Solvents	Petroleum, Refined	5	3		0	0	5
8032-32-4	LIGROINE	Solvents	Petroleum, Refined	3	2	0	0	0	5
7789-06-2	STRONTIUM CHROMATE	Metals	Chromium Compounds, Inorganic	5	3	3	0	0	5
7632-00-0	SODIUM NITRITE	Nitrogen Compounds	Nitrates and Nitrites	5	1	0	0	0	5
5989-27-5	D-LIMONENE	Other Classes	Terpenes	1	3	0	0	0	5

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
1309-60-0	LEAD DIOXIDE	Metals	Lead Compounds, Inorganic	5	4	4	0	0	5
7440-37-1	ARGON	Toxic Gases & Vapors	Simple Asphyxiants	1	1	0	1	0	4
141-78-6	ETHYL ACETATE	Solvents	Esters (<C12)	3	1		1	0	4
95-63-6	1,2,4 TRIMETHYLBENZENE; PSEUDOCUMENE	Solvents	Aromatic Solvents	3	2		1	1	3
630-08-0	CARBON MONOXIDE	Toxic Gases & Vapors	Chemical Asphyxiants	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	3
109-66-0	PENTANE	Solvents	Aliphatics, Saturated (<C12)	2	1	0	1	1	3
74-85-1	ETHYLENE	Toxic Gases & Vapors	Simple Asphyxiants	3	1		1	1	3
115-07-1	PROPYLENE	Toxic Gases & Vapors	Simple Asphyxiants	3	1	0	1	1	3
526-73-8	1,2,3-TRIMETHYLBENZENE	Solvents	Aromatic Solvents	3	3	0	1	1	2
108-67-8	MESITYLENE, 1,3,5-TRIMETHYLBENZENE	Solvents	Aromatic Solvents	2	2		1	1	2
107-83-5	2-METHYLPENTANE	Solvents	Aliphatics, Saturated (<C12)	3	2	0	1	1	2
71-43-2	BENZENE	Solvents	Aromatic Solvents	5	3		1	1	2

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
74-84-0	ETHANE	Toxic Gases & Vapors	Simple Asphyxiants	3	1	0	1	1	2
98-82-8	CUMENE	Solvents	Aromatic Solvents	5	1		1	1	2
91-20-3	NAPHTHALENE	Other Classes	Naphthalenes	5	3	0	1	1	2
111-84-2	NONANE	Solvents	Aliphatics, Saturated (<C12)	3	2	0	1	1	2
111-65-9	OCTANE	Solvents	Aliphatics, Saturated (<C12)	3	3		1	1	2
106-99-0	1,3-BUTADIENE	Plastics & Rubber	Other Monomers	5	1		1	1	2
592-41-6	1-HEXENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
90-12-0	1-METHYL NAPHTHALENE	Other Classes	Naphthalenes	4	4		1	1	2
106-98-9	1-BUTENE	Other Classes	Aliphatics, Unsaturated	1	1		1	1	2
620-14-4	3-ETHYLTOLUENE	Solvents	Aromatic Solvents	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
124-18-5	C10 AS N-DECANE	Solvents	Aliphatics, Saturated (<C12)	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
112-40-3	DODECANE	Other Classes	Aliphatics, Saturated (>C11)	1	1	0	1	1	2
10102-43-9	NITRIC OXIDE	Toxic Gases & Vapors	Oxidizers	5	3	0	1	1	2
629-62-9	C15 AS N-PENTADECANE	Other Classes	Aliphatics, Saturated (>C11)	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
1120-21-4	C11 AS N-UNDECANE	Solvents	Aliphatics, Saturated (<C12)	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
611-14-3	ETHYL TOLUENE	Solvents	Aromatic Solvents	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
108-95-2	PHENOL	Other Classes	Phenols	5	4		1	1	2
103-65-1	N-PROPYLBENZENE	Solvents	Aromatic Solvents	2	1	0	1	1	2
100-42-5	STYRENE	Plastics & Rubber	Styrenes	5	3	0	1	1	2
544-76-3	C16 AS N-HEXADECANE	Other Classes	Aliphatics, Saturated (>C11)	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
872-05-9	1-DECENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
622-96-8	4-ETHYLTOLUENE	Solvents	Aromatic Solvents	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
629-50-5	TRIDECANE	Other Classes	Aliphatics, Saturated (>C11)	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
109-67-1	1-PENTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
763-29-1	2-METHYL-1-PENTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
629-59-4	TETRADECANE	Other Classes	Aliphatics, Saturated (>C11)	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
28804-88-8	DIMETHYLNAPHTHALENE ISOMER	Other Classes	Naphthalenes	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2
691-37-2	4-METHYL-1-PENTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	1	2

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
91-57-6	NAPHTHALENE, 2-METHYL-	Other Classes	Naphthalenes	4	4		0	1	1
50-00-0	FORMALDEHYDE	Other Classes	Aldehydes	5	3	0	0	1	1
75-07-0	ACETALDEHYDE	Other Classes	Aldehydes	5	4	0	0	1	1
107-02-8	ACROLEIN	Toxic Gases & Vapors	Other Toxic Gases & Vapors	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
100-52-7	BENZALDEHYDE	Other Classes	Benzaldehydes	3	3		0	1	1
123-72-8	BUTYRALDEHYDE	Other Classes	Aldehydes	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
590-18-1	CIS-2-BUTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
4170-30-3	CROTONALDEHYDE	Toxic Gases & Vapors	Other Toxic Gases & Vapors	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
107-22-2	GLYOXAL, INHALABLE/VAPOR/AEROSOL	Other Classes	Aldehydes	5	3	0	0	1	1
590-86-3	ISOVALERALDEHYDE	Other Classes	Aldehydes	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
10102-44-0	NITROGEN DIOXIDE (NO2)	Toxic Gases & Vapors	Oxidizers	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
123-38-6	PROPIONALDEHYDE	Other Classes	Aldehydes	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
7446-09-5	SULFUR DIOXIDE	Toxic Gases & Vapors	Corrosive Gases	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
110-62-3	VALERALDEHYDE	Other Classes	Aldehydes	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
104-87-0	P-TOLUALDEHYDE	Other Classes	Benzaldehydes	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
124-11-8	1-NONENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
25339-56-4	1-HEPTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
25377-83-7	1-OCTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
4050-45-7	TRANS-2-HEXENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
513-35-9	2-METHYL-2-BUTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
529-20-4	O-TOLUALDEHYDE	Other Classes	Benzaldehydes	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
563-45-1	3-METHYL-1-BUTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
563-46-2	2-METHYL-1-BUTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
620-23-5	M-TOLUALDEHYDE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
627-20-3	CIS-2-PENTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
629-78-7	N-HEPTADECANE	Other Classes	Aliphatics, Saturated (>C11)	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
646-04-8	TRANS-2-PENTENE	Other Classes	Aliphatics, Unsaturated	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
78-85-3	METHACROLEIN	Other Classes	Aldehydes	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
78-98-8	METHYLGLYOXAL	Other Classes	Aldehydes	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	1	1
60-29-7	ETHYL ETHER	Solvents	Ethers (<C12)	2	2	0	1	0	1
68649-11-6	1-DECENE, DIMER, HYDROGENATED	Other Classes	Lubricants	2	2	0	0	0	0
NOCAS	NANOPARTICLES	Other Classes	Aerosol						

CAS #	Chemical Name	Major Category	Minor Category	HER - Inhalation	HER - Dermal	HER - Ingestion	F-22 Chemicals	HAS list	# of AFB Reporting Use
7440-43-9	CADMIUM	Metals	Cadmium Compounds, Inorganic	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	0	0
18540-29-9	CHROMIUM(VI)	Metals	Chromium Compounds, Inorganic	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	0	0
7440-41-7	BERYLLIUM	Metals	Beryllium Compounds, Inorganic	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	0	0
75-09-2	METHYLENE CHLORIDE	Solvents	Chlorinated Aliphatics	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	0	0
107-13-1	ACRYLONITRILE	Nitrogen Compounds	Nitriles	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	0	0	0
1066-40-6	TRIMETHYLSILONAL	Metals	Metalloid Compounds (Silicon)	NOT IN TOOL	NOT IN TOOL	NOT IN TOOL	1	0	0
NOCAS	RESPIRABLE PARTICULATE	Other Classes	Aerosol						
1333-86-4	ELEMENTAL CARBON/CARBON BLACK	Other Classes	Aerosol						
68937-41-7	PHENOL, ISOPROPYLATED, PHOSPHATE 3:1 (PIP 3.1 OIL)	Plastics & Rubber	Other Plasticizers	4	3	1	0	0	2

ACRONYMS

AI	Artificial Intelligence
AB	Air Base
AFB	Air Force Base
BE	Bioenvironmental Engineering
CASRN	Chemical Abstracts Service registry number
CHET	chemical hazard evaluation tool
EESOH-MIS	Enterprise Environmental, Safety, and Occupational Health Management Information System
EPA	Environmental Protection Agency
HAS	hardened aircraft shelter
HER	health effect rating
MAJCOM	Major Command
MELODI	Mining Enriched Literature Objects to Derive Intermediates
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RevMan	Review Manager