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NHTSA Advanced Anthropomorphic Test Devices Development and Implementation Plan

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Purpose:

This document outlines a plan detailing the development, documentation and agency actions associated with advanced anthropomorphic test devices (ATDs). This plan responds to a recommendation from the Government Accountability Office (GAO) in a report required by Section 24221 (GAO Report on Crash Dummies) of the Bipartisan Infrastructure Law (BIL). The GAO report is GAO-23-105595 (March 2023).

Reference Material:

GAO Report Conclusion (GAO-23-105595)[1] – Titled: DOT Should Take Additional Actions to Improve the Information Obtained from Crash Test Dummies:

> Vehicles and the safety features they offer—tested and refined by information provided by crash test dummies—play an important role in reducing risk of death and injury in crashes for all vehicle occupants. However, some demographic groups, including females, older individuals, and individuals with a higher body mass index, continue to face greater risks of injury or death. The characteristics and use of current dummies limit the extent to which the information they provide can reduce those greater risks. For example, the absence of lower leg instrumentation and reflection of female physiology in current dummies, how current dummies are used in crash tests, and limited understanding of how female bodies respond in vehicle crashes may limit the extent to which information collected from dummies in crash tests can mitigate risks for females. NHTSA has taken some actions to address these limitations, but its efforts have been incomplete in responding to existing risks, missed milestones, or not been well communicated. A comprehensive plan to respond to these risks, including timeframes and mechanisms for communication, would better enable NHTSA to improve safety for all, including those who face greater risks, and provide Congress, the public, and other stakeholders with information to hold NHTSA accountable on progress.

GAO Recommendation: The Administrator of NHTSA should develop and communicate a plan to address limitations in the information dummies provide related to the greater risks certain demographic groups face in vehicle crashes. Such a plan should detail how efforts will respond to risks, set milestones for activities, and establish mechanisms to communicate decisions and progress.

DOT Response dated February 7, 2023: The Department concurs. NHTSA is currently developing documentation on its planned research to further develop its crash test dummies, establish associated injury measures, and understand their utility in assessing vehicle safety for various demographic groups in the United States. This documentation will detail existing research plans and provide updates on the progress and timelines for the crash test dummies under development. NHTSA plans to publish the report by December 30, 2023.

Executive Summary:

In response to GAO-23-105595, NHTSA has developed the following plan discussing how the agency will address the limitations found in the information dummies provide relative to certain demographic groups. NHTSA is focused on reducing fatality and injury risk for all motor vehicle occupants and

[1] https://www.gao.gov/assets/gao-23-105595.pdf

addressing identified disparities expeditiously. NHTSA is taking several steps to address sex-based disparities in motor vehicle crash outcomes. These include the development of new biofidelic crash test dummies, collection of female specific injury data to establish sex-based injury criteria, the development of sophisticated computer modeling that can evaluate the effects of different types of crashes on a large range of human body types and sizes, research into the degree to which sex disparities in injuries exist in like crashes, and the evaluation of new safety standards.

The agency's research programs inform agency decision making from initial problem definition, to testing, data collection, and the development of safety tools. The safety tools and knowledge products developed through NHTSA research will address limitations in the information dummies provide related to greater occupant injury risk to certain demographic groups. These programs conduct research in two main research areas: computer simulation and physical testing.

In Part 1 of this plan, NHTSA provides an overview of the work NHTSA conducts to identify limitations in the information the dummies provide. NHTSA identifies these limitations by analyzing safety problems emerging in field data. NHTSA plans to continue its assessment of field data to identify real-world disparities in crash outcomes and develop research planning documents and analyses to understand such disparities.

In Part 2, the plan explains that test dummies are not the only tools being developed and applied to address injury risks across demographic groups. For decades, NHTSA and other government institutions, motor vehicle manufacturers, automotive safety equipment suppliers, and academic research institutions have been using computer simulations of crash environments to augment data from physical testing and make further improvements in vehicle crash safety. These tools have improved vastly over the years and are now highly developed and widely used. In some variability analyses, the best tool or tools could be finite element human body models (HBMs) representing a wide range of occupant sex, size, and age characteristics. In other considerations, such as for older occupants, applying different injury measures to collected data from physical tests that target performance thresholds that are more appropriate for vulnerable occupants may be necessary. NHTSA plans to consider applying such different injury criteria on data from advanced dummies such as THOR (50^{th} male and 5^{th} female – frontal impact) and WorldSID (50^{th} male and 5^{th} female – side impact).

Part 3 of this plan addresses the role that new crash test dummies play in mitigating injury risks for different populations. The agency describes a nine-stage process that spans the conception of a new ATD through its implementation in regulated and/or consumer information crash testing to show how NHTSA is addressing risks in occupant populations. It sets forth the agency's milestones for activities and establishes mechanisms to communicate decisions and progress relating to NHTSA's work in this area. In presenting these stages, the plan summarizes the six advanced dummies NHTSA currently has under development, the crash types in which they will be used, and how they will further advance occupant safety particularly for certain demographic groups. Further, the plan presents NHTSA's framework for progressing the development of these ATDs.

Part 1: Field Data and Research Planning Documents

NHTSA's mission is to save lives, prevent injuries, and reduce economic costs due to road traffic crashes, through education, research, safety standards and enforcement. One way we accomplish our mission is by studying real-world field data to understand the scenarios (crash types, road user characteristics,

vehicle designs) that contribute to observed injuries and fatalities. Often the data spawns research to understand the human response and tolerance to forces of vehicle occupants, pedestrians, and other road users in a crash, including among demographic groups.

This collective knowledge from the field data could lead to various agency activities, including the execution of new or updated ATD programs when warranted. When a new ATD is pursued, the agency develops specifications for ATD build, evaluates, and completes engineering assessments that provide the technical underpinnings for NHTSA's adoption of the ATD test tool. This data-driven approach provides the foundation for how NHTSA identifies the need, carries out the associated research, and adds ATD tools for use in agency crash testing programs to address motor vehicle crash-based injuries and fatalities.

Field Data Studies

NHTSA routinely analyzes real world motor vehicle crashes to quantify safety problems and identify emerging safety trends or new concerns. NHTSA will continue these field data studies to inform our research and crash testing tool/protocol development process. Continued effort in field data analysis will include documenting differences in injuries and crash factors for different populations of vehicle occupants, including those with greater risk of injury and fatality. Past efforts have included studies assessing injury rates for elderly, obese, and female occupants to evaluate possible risk disparities of these demographic groups. In 2013, NHTSA reviewed the relative risk of moderate or serious injury for older occupants using the National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) from 2001 to 2011.[2] Elderly occupant drivers, right front passengers, and second row passengers experienced increased injury risks when compared to the 35–54-year-old age group. As compared to the 35-to-54 age group, the 85 and older age group had 1.77 times higher risk of injury for drivers and 5 times higher risk for right front passengers. In 2019, NASS-CDS frontal crashes for belted occupants were reviewed to compare moderate or greater injury risks for obese occupants with non-obese occupants.[3] Obese occupants exhibited significantly greater injury risk in the thorax, spine, upper extremities, and lower extremities.

NHTSA has published recent field data studies evaluating injury and fatality risk differences between males and females. Noh et al. (2022)[4] studied relative fatality risk utilizing paired comparisons of adult females and males utilizing Fatality Analysis Reporting System (FARS) data from 1975 to 2019. A similar earlier version of paired analysis published by NHTSA in 2013[5] found females to have 17% higher relative fatality risk than males. While the 2022 study also found an overall increase (15.5% for the same age range of occupants, 21 to 96), both overall estimates were made using vehicle model year ranges that dated back to the 1960s and had a majority of cases where vehicles were not equipped with airbags. Noh et al. (2022) also found that when considering newer vehicles with the latest generation of

[2] https://www.nhtsa.gov/sites/nhtsa.gov/files/older_people_811873.pdf
[3] https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/sae_gi_joodaki_04_01_2019-tag.pdf
[4] Noh, E. Y., Atwood, J. R. E., Lee, E., & Craig, M. J. (2022, August) Female crash fatality risk relative to males for similar physical impacts (Report No. DOT HS 813 358). National Highway Traffic Safety Administration.
[5] Kahane, C. J. (2013, May). Injury vulnerability and effectiveness of occupant protection technologies for older occupants and women. (Report No. DOT HS 811 766). National Highway Traffic Safety Administration.

airbags and seatbelts, the relative risk difference between females and males was significantly reduced (e.g., 2.9% for model years 2015 to 2020).

NHTSA also uses its Crash Injury Research and Engineering Network (CIREN) to identify emerging trends in motor vehicle crash injuries and fatalities. Data collected through CIREN includes detailed information on the crash, the occupant (or pedestrian), and the injuries sustained, all of which guide NHTSA research planning. A unique benefit of the CIREN program is collaboration between medical doctors and engineers, which contributes additional insight to understanding crash injury causation. Using CIREN data, CIREN researchers have conducted numerous studies examining the effects of age, body mass index, and/or sex on injury outcomes[6]. Currently, NHTSA has three ongoing CIREN research projects focusing on a variety of sex-based differences in injuries including those to the thorax, lower spine, abdomen, pelvis, and lower extremities.

As discussed below, the results of these field studies, such as the examples above, have historically guided NHTSA research planning, research focus areas, and ATD development, where appropriate, to further address crash safety for all users.

Research Planning Documents

NHTSA will continue to analyze findings from the above field data-based studies and similar efforts to guide research to understand why people are getting injured and how certain characteristics such as age, sex, and size may contribute to injury risk.

Focusing on female crash safety, in 2022, NHTSA has developed and publicly shared a plan for how we are researching to address injury risk for females.[7] This research plan describes the field data, experimental biomechanics, ATD, human body modeling, and fleet testing/countermeasure study efforts aiming to address three questions:

(1) What is the current state of knowledge on fatality and injury risk for females involved in motor vehicle crashes?
(2) What are the causes of elevated motor vehicle crash related risk for females?

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[6] Example studies include:

- Weaver, A. A., et al. (2019), Sarcopenia and osteosarcopenia in seriously injured motor vehicle crash occupants. Traffic Injury Prevention 20(sup2): S195-S197.
- Joodaki, H., Gepner, B. D., McMurry, T. L., Kerrigan, J. R. (2020), Comparison of injuries of belted occupants among different BMI categories in frontal crashes. International Journal of Obesity, 44(6): 1319-1329. https://doi.org/10.1038/s41366-019-0481-2
- Armstrong, W., Costa, C., Poveda, L., Miller, A. N., Ambrosini, A., Hsu, F., Kiani, B., Martin. R. S., Stitzel, J. D., Weaver, A. A. (2022), Effects of muscle quantity and bone mineral density on injury and outcomes in older adult motor vehicle crash occupants. Traffic Injury Prevention, 23(sup1), S86-S91, DOI https://doi.org/10.1080/15389588.2022.2124864
- Weaver, A. A., Ronning, I. N., Armstrong, W., Miller, A. N., Kiani, B., Martin, R. S., Beavers, K. M., Stitzel, J. D. (2023), Computed tomography assessment of pelvic bone density: associations with age and pelvic fracture in motor vehicle crashes. Accident Analysis and Prevention, 193(2023) 107291, DOI https://doi.org/10.1016/j.aap.2023.107291
- Firey, L. M., Rudd, R. W., Lockerby, J., Craig, M. J. (2023), Identification of influential factors among fatalities of restrained first-row occupants in recent frontal crashes, International Research Council on Biomechanics of Injury Conference, Cambridge, UK, https://www.ircobi.org/wordpress/downloads/irc23/pdf-files/2311.pdf
- Rudd, R. W., Parenteau, C. S. (2023), Serious spine injuries using 2017-2021 CISS and CIREN data: Effect of spinal degeneration comorbidities, International Research Council on Biomechanics of Injury Conference, Cambridge, UK, https://www.ircobi.org/wordpress/downloads/irc23/pdf-files/2310.pdf

[7] https://www.regulations.gov/document/NHTSA-2022-0091-0002

(3) What can be done to better protect females in motor vehicle crashes?

The Female Crash Safety Research Plan describes numerous efforts that are either now completed and published (e.g., field studies from 2022 and 2023 described above; development of a 50th female human body model) or are in process (e.g., data collection to support biofidelity and anthropometry specifications for an average female; small female ATD development and documentation efforts). The ATD aspects of that plan are described in detail in Part 3 of this plan.

NHTSA published a similar plan addressing traffic safety for older people (NHTSA, 2013[8]) focusing on various aspects of occupant and pedestrian safety including aspects of vehicle design and older occupant frailty and fragility. That plan included near-, short-, and long-term elements including injury risk/injury tolerance and ATD applications and development of human body models, both areas in which NHTSA has since completed and published a significant amount of research[9].

Part 2: ATD Considerations & Virtual Testing as a Supplement

Historically, motor vehicle crash safety tools have taken the form of physical crash test dummies or ATDs that predict injury risk from the measured mechanical response of the instrumented ATD; however, it is not practical to develop a different crash test dummy for all types of road user characteristics, and there is no evidence to suggest that use of many ATDs is necessary to advance crash safety for all or address crash outcome disparities. Current regulated adult crash test dummies generally represent a small female and a midsized male. NHTSA uses these test dummies in mandated crash tests to assure vehicle protection for a wide range of occupant sizes. To address a wider range of occupant characteristics (height, weight, age, sex), NHTSA's plan is to use simulation tools and virtual testing of vehicles with a wide range of validated finite element ATD and human body models as a supplement to physical crash tests. These tools can utilize the measurements from a single crash test to understand the safety outcomes for a wide range of body types. NHTSA described this methodology in the agency's Interim Report to Congress – Crash Test Dummies (September 2022),[10] which NHTSA developed pursuant to § 24221(b) of the Bipartisan Infrastructure Law. The Insurance Institute for Highway Safety (IIHS)[11] and the European New Car Assessment Programme (Euro NCAP[12]) also believe that physical crash test dummies are not necessarily the solution to address equity and the wide range of road user characteristics.[13]

NHTSA's plan recognizes that advancements in virtual testing tools enable improved occupant protection in the future. NHTSA has long supported the development of computer simulation models of

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[8] https://www.nhtsa.gov/sites/nhtsa.gov/files/older_people_811873.pdf

[9] Examples of completed research include the development of a 50th female human body model (https://www.ghbmc.com/) and a number of publications.
http://www.ircobi.org/wordpress/downloads/irc18/pdf-files/103.pdf;
http://www.ircobi.org/wordpress/downloads/irc23/pdf-files/2311.pdf;
http://www.ircobi.org/wordpress/downloads/irc23/pdf-files/2346.pdf;
http://www.ircobi.org/wordpress/downloads/irc23/pdf-files/2375.pdf.

[10] NHTSA, 2022. Interim Report to Congress – Crash Test Dummies. https://rosap.ntl.bts.gov/view/dot/64706

[11] https://www.iihs.org/news/detail/improving-safety-for-women-requires-more-than-a-female-crash-test-dummy ; https://www.iihs.org/topics/bibliography/ref/2219

[12] https://www.euroncap.com/en/press-media/press-releases/euro-ncap-vision-2030-a-safer-future-for-mobility

[13] EuroNCAP, as well as NHTSA, recognize that it is not feasible to develop an ATD for every demographic group and conduct physical testing for each of these groups. As such, NHTSA and others recognize the key to mitigating occupant injury risk for certain demographic groups will lie in a coupling of physical testing with virtual testing.

humans, crash test dummies, and vehicles. The finite element human body models (HBMs) developed by the Global Human Body Models Consortium (GHBMC) have been used to assess injury in greater risk groups.[14] This work has included, but is not limited to, the development of HBMs for a 75-year-old[15] as well as a 50th percentile female,[16] the assessment of thoracic geometry and changes with age,[17] and evaluation and application of high body mass index (BMI) HBMs in vehicle safety system optimization studies.[18] These state-of-the-art tools can be used in studying injuries and injury causation as well as developing more advanced vehicle structures and restraint systems. While it is not feasible to run an actual crash test to answer every research question related to occupant safety, computer simulations approach offers a fast, efficient, and comprehensive method to estimate potential outcome changes for reasonably varied scenarios around the physical tests. This is particularly valuable when assessing the influence of small perturbations in occupant centric measures (e.g., anthropometry and seated posture).

However, while industry and researchers also use simulation models extensively, establishing objective standards and criteria for simulation tools that are accepted by all users remains challenging. There are many important considerations with these simulation techniques. Primarily, such models need to be validated in real-world or standardized, crash test conditions. Researchers are working to overcome these challenges to better leverage virtual modeling as a safety tool. For example, Euro NCAP Vision 2023 strives to bring protection equity through modeling by 2032.[19]

To this end, Part 2 of NHTSA's plan is supporting research to develop and demonstrate a framework for virtual testing as a supplement to physical testing. These efforts are exploring the application of virtual human body models in simulated vehicle crash environments. The human body models will represent males and females of various sizes, shapes, and ages representing a high percentage of motor vehicle occupants. Research efforts are also documenting human variability considerations that could be adopted into human body models (e.g., changes in body shape or geometry for a given anthropometry such as 50th percentile female). This research program includes efforts to validate the human body models, since establishing standards and criteria for specific simulation tools to be used and accepted by all users for vehicle safety assessments presents challenges.[20] Finally, this effort may also explore options for how ATD models could be used as part of virtual testing efforts similar to efforts being proposed by Euro NCAP.[21]

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[14] NHTSA, 2022. Interim Report to Congress – Crash Test Dummies. https://rosap.ntl.bts.gov/view/dot/64706

[15] Umale, S., Khandelwal, p., Humm, J.R., and Yoganandan, N. (2022) An investigation of elderly occupant injury risks based on anthropometric changes compared to young counterparts, Traffic Injury Prevention, 23:sup1, S92-S98, DOI: 10.1080/15389588.2022.2135373

[16] https://www.regulations.gov/document/NHTSA-2022-0091-0002

[17] Weaver, A.A., Schoell, S.L. and Stitzel, J.D. (2014), Morphometric analysis of variation in the ribs with age and sex. J. Anat., 225: 246-261. https://doi.org/10.1111/joa.12203

[18] https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/sae_gi_joodaki_04_01_2019-tag.pdf

[19] https://cdn.euroncap.com/media/74468/euro-ncap-roadmap-vision-2030.pdf

[21] https://cdn.euroncap.com/media/77295/euro-ncap-far-side-test-and-assessment-protocol-v24.pdf

Part 3: Development of New Crash Test Dummies

Background

ATDs are currently the primary form of safety tools for occupant protection within Federal Motor Vehicle Safety Standards (FMVSS) and NHTSA's New Car Assessment Program (NCAP). These ATDs must be rigorously developed to accurately represent human kinematics, injury potential and interaction with vehicle environments and safety countermeasures. NHTSA has documented the ATD development process following well defined stages of research, outreach and agency decision making. This plan responding to GAO-23-105595 (March 2023) outlines the nine major stages involved in the development and finalization of ATD safety test tools. Each stage will describe the relevant stage, any agency decisions, risk mitigation, outreach, and an estimate of typical timing.

NHTSA's Interim Report – Crash Test Dummies (2022),[22] summarized the status of ATDs in regulation, ATDs that are under development, and their use within FMVSS and NCAP. ATDs must be biofidelic (must be sufficiently representative of a human), durable, and must produce valid and reliable data. Current ATDs met repeatability, durability, and biofidelity requirements when introduced into FMVSS years ago. Today, ATDs under development must also meet these requirements but must do so with additional instrumentation in updated body regions, thereby expanding the suite of testing required to create a quality dummy. They are designed to address a specific crash mode (e.g., frontal crashes), occupant type (sex, size, and age), and associated injuries (e.g., head, neck, chest, femur). For ATDs like the THOR 50th percentile male (THOR-50M) and 5th percentile female (THOR-05F) frontal ATDs, we have been targeting enhanced humanlike response and expanded instrumentation to provide capabilities to mitigate against a wider range of injuries than those measured by the current ATDs (Hybrid III 50th male and 5th female). For the specific example of the THOR ATDs, this means being able to measure for injuries to the chest, abdomen, acetabulum, leg, and ankle in ways that current ATDs cannot. Application of such advanced ATDs in crash testing programs in conjunction with specific injury criteria established for target groups would drive the development of safety countermeasures that will reduce injury risk for both females and males.

ATD Development Process

In the context of crash test dummies, NHTSA's statute in the Motor Vehicle Safety Act requires the agency to demonstrate and document the biofidelity, durability, repeatability, and reproducibility of a new ATD, develop associated injury criteria, and demonstrate its use in crash testing protocols. Once these steps are complete, the remaining steps focus on the process to formalize the ATD. This is done by publishing the final documentation and providing public notice and comment on the definition of the ATD and its implementation in FMVSS in the Code of Federal Regulations (CFR). Parallel efforts may be carried out to define the use of the ATD in NHTSA's NCAP. To meet these obligations, NHTSA utilizes a nine-step process[23] that uses decision gates where readiness decisions are made related to whether to proceed to the next phase of the effort (and commit associated personnel and funding).

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[22] NHTSA, 2022. Interim Report to Congress – Crash Test Dummies. https://rosap.ntl.bts.gov/view/dot/64706

[23] NHTSA's ATD development process follows a similar flow that the generally known Stage Gate process includes (https://asana.com/resources/stage-gate-process).

The main stages[24] for the specification, procurement, testing and evaluation, technical documentation, demonstrated application, and rulemaking for advanced ATDs are shown below.

1. Define/Document Need
2. Develop Specifications
3. Procurement/Development/Acquisition
4. Inspection and Evaluation
5. Demonstrated Application in Targeted Test Conditions
6. Development/Finalization of Technical Documentation
7. Development, Drafting, and Public Notice
8. Respond to Public Comments
9. Finalize and Publish Implementation Plans

This process for ATD development communicates the plan for how NHTSA is using physical development and testing of ATDs to address limitations in the information dummies provide related to the greater risks for certain demographic groups. Appendix B includes detailed status of each stage for the THOR-05F. By including the THOR-05F as an example, this plan communicates how advancements in ATDs can improve the information they provide to address female injury risks. The subsequent plan details how NHTSA sets milestones for activities and establishes mechanisms to communicate decisions and progress throughout the lifecycle of ATD development.

ATD Development and Documentation Plan:

The following sections detail the 9 stages of ATD development that NHTSA follows. Each stage includes sections providing a *Description*, *Agency Action*, *Timing/Duration*, *Stage Risks,* and *Communication of Decisions/Progress* that detail the content for each stage. Additionally, Appendix A provides a summary of the respective status of ATDs NHTSA is currently working on with respect to the stages presented herein. Appendix B provides an expanded written summary of completed and in-process stages for the THOR-05F.

Stage 1: Define/Document Need

> ***Description***: This first step is where through various means (field data analysis, crash simulation, physical testing) a demonstrated need for a new crash testing tool is documented (e.g., a new ATD or a new finite element HBM). Such need-based documentation aims to describe the safety need for the new crash testing tool (e.g., crash type, summary of injury outcomes, summary of current tools/regulations/testing, occupant characteristics). The documentation of need should address the projected benefits of the new tool.
>
> For example:
>
> - Projected improvements in biofidelity/instrumentation vs. a current ATD of similar anthropometry (e.g., 5th percentile female or 50th percentile male).

[24] The Stage Gate Process typically includes: (a) Discovery; (b) Scope; (c) Business Case; (d) Development; (e) Test and Validate; and (f) Launch. For ATD development it could be argued that item 1 above aligns with (a and b); item 2 aligns with (c); item 3 aligns with (d); items 4 to 6 align with (e); and items 7 to 9 align with (f).

- Societal benefits of adding a new ATD of a unique anthropometry or percentile vs. current ATDs (e.g., 50th female frontal ATD or a high body mass/obese ATD) and how that ATD would address a gap or gaps in the representation of a population and/or how use of that ATD together with existing ATDs would change how vehicles are designed through the development of improved crashworthiness countermeasures that reduce injury and fatality risk for a greater range of motor vehicle occupants.

Agency Action: A technical assessment is required before moving to Stage 2. The agency must also determine that the safety need is commensurate with the time (often more than 10 years) and resources (often greater than $20M plus associated federal and contractor full time employees or FTEs) involved to complete an ATD development program. The agency decision would also be informed by whether there are other means, such as virtual testing and human body modeling that may address the targeted crash/injury/human characteristics outcomes.

Timing/Duration: If a new ATD is replacing an existing ATD of similar anthropometry, the timing of this stage can be measured in months as what is generally being presented are differences in biofidelity and instrumentation (e.g., THOR-50M vs. Hybrid III 50th male). Stage 1 duration can be considerably longer (1+ years) if making a data driven case for an ATD of a new or unique anthropometry.

Stage Risks: GAO's conclusions and recommendations are referring to "risks" in terms of injuries and fatalities for different populations of road users/motor vehicle occupants. These types of risks (i.e., injury risks) are managed in the ATD specification and development process by thoroughly studying and documenting the requirements for ATD development in Stage 1. This can include demographic factors such as size, height, age, sex as well as representative crash testing protocols and injury metrics that may be required to address various crash scenarios and injury outcomes. Beyond Stage 1, the remaining ATD formulation, build, testing, documentation, and rulemaking steps coupled with appropriate crash testing protocol development and applications, aim to reduce injury and fatality risks as comprehensively as possible.

In developing and documenting a new ATD, risks can also be defined by program or project management related issues that may result in missed milestones, which was a key component of GAO's findings.[25] For stage 1 program or project related risks, NHTSA plans for staff resources to support field data and engineering analysis to document the need for a new ATD (i.e., resource plan with defined roles/responsibilities and level of effort). This staff resource need for Stage 1 is often preceded by agency efforts to support programs that provide access to detailed motor vehicle crash injury data such as CISS and CIREN that are used to study injury and fatality trends and identify possible gaps in current testing protocols (ATDs, injury measures, test conditions) that can be addressed, in part, by new ATDs.

Communication of Decisions/Progress: Decisions to proceed with the next stages of the development of a new ATD are communicated via NHTSA Research Public Meetings and/or other public forums.

[25] https://www.gao.gov/assets/gao-23-105595.pdf

Stage 2: Develop Specifications

Description: Upon completion of Stage 1, this next step focuses on the development and documentation of specifications for the prospective new ATD, such as those for biofidelity response requirements, anthropometry targets, durability requirements, initial drawing package (if appropriate), and required instrumentation. This step, in part, acts to address the GAO recommendation related to the limitations of information coming from current ATDs by specifying biofidelic designs with instrumentation that can better measure injury potential for sub-populations of human occupants an ATD is designed to represent. This would include specifications and instrumentation for body regions that are underrepresented in current crash testing (e.g., lower leg, foot, ankle). Notably, some data developed in this stage is not limited to applications on ATDs but can also be used in the development and validation of finite element human body models in support of virtual testing applications.

Agency Action: Completion of ATD technical specification documentation is required to progress past Stage 2. The agency would review the documentation and other factors, such as other global activities underway, to decide on the initiation for the ATD development and procurement steps for Stage 3.

Timing/Duration: Pending the level of effort (new ATD of an existing anthropometry with well-described biofidelity specifications vs. brand new ATD with unique anthropometry) this step could take few months or up to five years. The longer timeline would be in cases, for example, where new biofidelity (human response) or anthropometry data is required to support dummy specifications. Those studies on their own can take multiple years.

Stage Risks: Developing biofidelity, anthropometry, and other requirements for a new ATD can take a significant amount of time. To minimize the timing impact of developing such specifications, alternative data sources (e.g., outside of NHTSA) or methods to develop biomechanical response requirements (e.g., use of virtual tools to aid in specification development) are often utilized. To maximize transparency, NHTSA publishes technical literature and seeks public comment on possible design specifications as well as overall plans for introducing a new ATD (e.g., definition of need; targeted design requirements such as biofidelity and instrumentation). To minimize the risk of ATD re-design due to issues discovered in Stage 4 or 5 (e.g., ATD durability), extra care needs to be taken in this stage to develop design specifications that consider known ATD design failure modes.

Communication of Decisions/Progress: A public meeting to facilitate interaction with technical experts, industry, other government organizations, and the public is often held to seek input and provide status on plans to develop specifications for a new ATD. NHTSA research plans and status have also been shared at annual NHTSA Research Public meetings or similar public venues. NHTSA's research plans regarding ATDs are also released to the public in the form of Annual Modal Research Plans (AMRPs).[26] Finally, technical documents and specifications are often published by NHTSA in a research docket (similar to THOR-05F in Appendix B).

[26] https://www.transportation.gov/administrations/assistant-secretary-research-and-technology/rdt-annual-modal-research-plans

Stage 3: Procurement/Development/Acquisition

Description: This stage covers the steps necessary to engineer/manufacture prototypes of a new ATD. Multiple possible paths exist regarding how such prototypes can be sourced/produced (e.g., internal prototyping; contracting to ATD manufacturers; contracting to academic institutions). Specifications developed in Stage 2 are applied towards the ATD procurement and development actions of Stage 3.

Agency Action: NHTSA conducts market surveys to determine the procurement method, execute contracts, and perform acceptance testing. An ATD development contract is developed, including in budget forecasting, annual modal research planning, and fiscal year spend planning efforts (and associated approvals). NHTSA Vehicle Safety Research and assigned Contracting Officer's Representative (COR) (in the case of traditionally procured ATD prototypes) will need to evaluate and approve the delivery of prototype ATDs. This acceptance testing may involve overlap into Stage 4 efforts to provide initial evaluation and inspection of delivered prototype ATDs.

Timing/Duration: Stage 3 generally takes up to a year to develop, issue request(s) for proposals, and award contracts for ATD engineering/prototyping. Once a contract is awarded (if following a traditional ATD development path), it can take from one to three years to receive initial prototypes.

Stage Risks: An option would often exist (pending availability of funds) to pursue multiple development paths with more than one ATD vendor. Additionally, NHTSA can pursue procurement efforts that include not just engineering and manufacturing, but also biofidelity and durability performance verification requirements to ensure the initial prototype ATDs meet specifications and to reduce likelihood of a need for a significant re-design cycle of the ATD (e.g., due to durability issues discovered during Stage 4 or 5).

Communication of Decisions/Progress: Issuance of a request for proposal and selection of contractors (if choosing a traditional ATD development path) are communicated via appropriate acquisitions channels. Technical articles and public presentations are developed to share progress with industry and academia. Project status and descriptions are published at the Department of Transportation (DOT) Research Hub (https://researchhub.bts.gov/search).

Stage 4: Inspection and Evaluation

Description: Stage 4 involves NHTSA's efforts to inspect and evaluate (e.g., as compared to drawing package, biofidelity specifications, durability requirements) the prototype ATD prior to proceeding to the more extensive efforts described in Stages 5 and 6.

Agency Action: Coupled with Stage 3, this step involves NHTSA actions to evaluate and inspect a prototype ATD.

Timing/Duration: This task, pending the findings of initial evaluations and demonstrated application, can be measured in years (e.g., in instances where biofidelity or durability concerns exist that necessitate design changes). If issues are discovered upon inspection and evaluation (e.g., durability), there may be a need to return to Stage 3 to procure updated ATD hardware.

Stage Risks: Risk associated with the need to return to Stage 3 for dummy re-design issues (e.g., due to durability failures) can be mitigated in the ATD specification and procurement phases (Stage 2 and 3).

Communication of Decisions/Progress: Like earlier stages, progress is typically shared through technical articles and public presentations at venues such as NHTSA's Research Public Meeting.

Stage 5: Demonstrated Application in Target Test Conditions

***Description*:** This stage evaluates the performance of the prototype ATD in motor vehicle crash test conditions. Some testing can be done in parallel to Stage 4 and supports documenting durability or general design issues that may need to be addressed. Additionally, absent significant ATD design concerns, this stage would aim to demonstrate the benefit of using a new ATD in targeted crash testing applications. Often technical documentation will contrast injury measures and crash performance compared to a contemporary ATD. This step, in part, acts to address the GAO recommendation related to the limitations of information provided by current ATDs by developing test protocols and performance measures that can maximize injury mitigation potential using new ATDs in conditions where motor vehicle occupants continue to be seriously injured or killed in motor vehicle crashes. In this step, characteristics of greater risk occupant groups are assessed for influence on developed ATD performance measures.

This may sometimes entail development and/or demonstration of crash testing protocols for a new ATD. This could also entail parallel programs and agency consideration of alternative protocols. As with ATDs, crash testing protocols require similar development and technical documentation (e.g., barrier design specifications; performance criteria) as well as injury performance measures. Status of these activities for different ATDs are presented in Table 1 and Appendix A.

This stage does not need to be limited to new ATDs but could also revisit regulatory and consumer metric testing programs by considering expanded application of ATDs in crash testing (e.g., driver and rear seat seating positions in frontal crash tests for small female ATDs). In general, NHTSA is taking steps in this stage to address GAO concerns regarding the extent to which ATDs can provide useful information that can be used to reduce injury risks, including in cases where there are differences in risk for different populations (females, older occupants, obese). This is done by demonstrating the utility of a new ATD and potential benefits of its application in contrast to contemporary ATDs and can also include exploration of new testing protocols (e.g., frontal oblique crashes).

Agency Action: This ATD stage is generally coupled with a test protocol-based development effort or demonstration of utility in existing protocols. The agency would consider results of Stage 5 and Stage 6 in deciding whether to initiate efforts to include the new ATD in the agency's regulations for ATDs (49 CFR Part 572 – Anthropomorphic Test Devices). The agency would also consider potential inclusion in future agency recommendations, requirements, or consumer information programs.

Timing/Duration: Stage 5 can take two or more years and can be done in parallel to Stage 6. Alternatively, findings from NHTSA testing during Stage 5 (e.g., durability issues) may result in a

return to Stage 3 and 4 to address ATD design issues. Findings related to ATD performance may also be identified by external stakeholders during this stage. Mitigation of such re-design needs is described in Stage 2 and 3.

Stage Risks: NHTSA plans for resources to complete as much testing as possible early in the ATD development cycle to identify any possible areas for remediation (e.g., durability issues). If required, once design updates are complete and deemed satisfactory, NHTSA will demonstrate a new ATD's performance and utility in a range of current and/or new crash testing protocols. Provisional injury criteria are often applied as needed and results/findings are updated at a later date once final ATD injury criteria are well-defined and peer reviewed.

Communication of Decisions/Progress: Like prior stages, status of Stage 5 efforts would be shared in technical journals, public meetings and/or conferences.

Stage 6: Research to Support Development/Finalization of Technical Documentation

Description: This stage serves to complete all the necessary testing and documentation needed to adequately describe the ATD for standardization purposes. Documentation includes reports covering repeatability and reproducibility; durability; biofidelity; ATD qualification procedures; procedures for assembly, disassembly, and inspection; drawings; seating procedure; and injury criteria. As in stage 5, NHTSA will consider data and information from external stakeholders to support the completion of ATD technical documentation.

Agency Action: The results of Stage 5 and Stage 6 together would be used to support an agency deliberation on whether to initiate efforts to include the new ATD in Part 572 and agency crash testing programs.[27]

Timing/Duration: This stage can be done in parallel to Stage 5. The full timeline of efforts includes the testing, drafting of documentation, agency review, and docketing of materials.

Stage Risks: To manage risks that produce delays in later steps, this step would consider efforts to finalize technical documentation while simultaneously developing and drafting test procedures and related documentation.

Communication of Decisions/Progress: Similar to prior stages, status of Stage 6 efforts would be shared in technical journals, federal notices, public meetings, or technical meetings/workshops/conferences.

Stage 7: Development, Drafting, and Public Notice

Description: This step generally follows Stage 5 and 6 and represents the official drafting, agency review, and public notice of agency plans including any requests for comment. This stage typically would focus on efforts to add it to Part 572. Efforts to pursue inclusion of an ATD in Part 572 would often be done in parallel to efforts to utilize the ATD in appropriate agency testing programs.

[27] https://www.reginfo.gov/public/do/eAgendaMain

Agency Action: Publish notice(s) of proposed rulemaking associated with ATD inclusion in Part 572 and as appropriate accompanying notices for inclusion in agency test programs.

Timing/Duration: This step can often take a year or more to accomplish (initiation of drafting documents to their publication in the Federal Register).

Stage Risks: To minimize time and effort, NHTSA uses content precedent (e.g., prior dummy rulemakings) to aid development of the documentation (e.g., THOR-05F documentation can mirror content developed for THOR-50M as appropriate).

Communication of Decisions/Progress: Generally, communication of formal agency plans would be via the Regulatory Agenda.[28] Subsequent actions would be published in the Federal Register and seek public comment (e.g., see THOR-50M Part 572 Notice of Proposed Rulemaking or NPRM below[29]).

Stage 8: Respond to Public Comments

Description: Stage 8 is the interim step in the implementation process where NHTSA will review and develop responses and pursue actions, if needed, to address comments received in response to notices published as part of Stage 7.

Agency Action: Actions for this step typically to involve decisions on possible additional data collection, testing, analysis, and research needed to respond to public comments before proceeding to Stage 9.

Timing/Duration: It typically requires at least one year from the date of a request for comment being published (Stage 7) to the date an agency response is published (Stage 9). The time in between (Stage 8) represents the period in which NHTSA receives and develops responses to public comments in preparation for drafting of the final decision notices relating to an ATD and its usage (Stage 9). Recent ATDs have taken from two years (ES-2re and SID-IIs) to eight years (Q3s) from the publication of an NPRM to the publication of a final rule to add the respective ATDs to Part 572.

Stage Risks: Efforts and timing related risks present at this stage depend on the nature of the individual ATD, its intended usage and public response to agency efforts in developing and describing the ATD in stages 1 to 7.

Communication of Decisions/Progress: Communications regarding our response to items in Stage 8 would be presented in formal agency notices in Stage 9.

Stage 9: Finalize ATD and Publish Implementation Plan

Description: This is the final step in the ATD development and implementation process. This stage involves the drafting of the final test procedures and assessment methodologies. When complete and approved, the ATD would be included in Part 572 through publication in the Federal Register. This may be done in coordination with public notices for agency crash testing

[28] https://www.reginfo.gov/public/do/eAgendaMain
[29] https://www.federalregister.gov/documents/2023/09/07/2023-19008/anthropomorphic-test-devices-thor-50th-percentile-adult-male-test-dummy-incorporation-by-reference

program plans. Some testing programs may have corresponding phase in periods that reflect the timing of when NHTSA will commence with using the respective ATDs.

Agency Action: Develop, review, and publish final notice(s).

Timing/Duration: See above timing in Stage 8.

Stage Risks: There are no unique execution risks in this stage. Success in this stage will be predicated on the execution of stages 1 to 8.

Communication of Decisions/Progress: Status is provided in formal agency publications including the regulatory agenda, Federal Register and Code of Federal Regulations.

Summary:

NHTSA follows the same nine stages for all ATD development programs. Table 1 shows the completed and ongoing (X) stages for the ATDs described in our interim report responsive to BIL 24221.[30] Multiple stages are often ongoing simultaneously where elements can be done in parallel. Stages 5 to 9 often require research to develop or enhance crash testing protocols for use with new ATDs. The development and initial evaluation of new crash testing protocols have stages similar to 1 to 4 described for ATDs. The test procedures or protocols (status shown in Table 1 for each ATD) are an important research element to the final utilization of ATDs. Such efforts can also include decisions on ATD application in different vehicle seating positions for agency crash testing programs. See Appendix A for detailed status of the ATDs in listed in Table 1.

[30] NHTSA, 2022. Interim Report to Congress – Crash Test Dummies. https://rosap.ntl.bts.gov/view/dot/64706

Table 1: Summary of NHTSA in-process ATDs (and associated crash testing protocols).

ATD	**Stage 1** *Define Need*	**Stage 2** *Develop Specs*	**Stage 3** *Build / Procure*	**Stage 4** *Test / Evaluate*	**Stage 5** *Crash Testing*	**Stage 6** *Finalize Docs*	**Stage 7** *Publish Notice*	**Stage 8** *Public Comments*	**Stage 9** *Finalize*
THOR 50th Percentile Male Frontal Impact ATD								X	
FMVSS No. 208/NCAP						X	X		
THOR 5th Percentile Female Frontal Impact ATD				X	X				
FMVSS No. 208/NCAP				X	X				
WorldSID 50th Percentile Male Side Impact ATD						X			
FMVSS No. 214/NCAP						X	X		
WorldSID 5th Percentile Female Side Impact ATD			X	X					
FMVSS No. 214/NCAP				X					
LODC 10-year-old Child ATD			X	X	X	X			
FMVSS No. 213				X	X				
BioRID-II Average Male Rear Impact ATD				X	X				
FMVSS Nos. 202a/207				X					

Shaded cells represent completed stages; X represents a current stage of activity; activities can occur simultaneously across stages.

Conclusions:

NHTSA is focused on reducing fatality and injury risk for all motor vehicle occupants and is also committed to addressing sex-based disparities in motor vehicle crash outcomes. We have several tools at our disposal to support these efforts including new biofidelic crash test dummies and sophisticated computer models that can evaluate the effects of different types of crashes on a large range of human body types and sizes.

The three-part plan outlined above communicates NHTSA's plan to address limitations in the information dummies provided related to greater risk occupants. In Part 1, field data are leveraged to analyze emerging safety problems. This analysis identifies vulnerabilities within crashworthiness across all occupant demographics. These vulnerabilities spawn research to better understand the human response and tolerance, manifesting in dummy and virtual model improvements. Parts 2 and 3 identify two research areas used to respond to the risks identified in Part 1. In Part 2, NHTSA supports research to demonstrate a framework for virtual testing as a supplement to physical testing, thereby enabling more demographic focused testing. In Part 3, a streamlined process for ATD development addresses limitations in the information provided by current ATDs. This process communicates how NHTSA sets

milestones for activities and established mechanics to communicate decisions and progress throughout the lifecycle of ATD development.

Appendix A:

The following is a summary of the ATDs that NHTSA currently has in development and description of current stage activities for each ATD shown in Table 1.

THOR 50th Percentile Adult Male Frontal ATD (THOR-50M):

The THOR-50M represents a mid-sized adult male and has a seated height of 94 cm (37 in), an approximate standing height of 175 cm (68.9 in), and a weight of 76 kg (167.6 lbs). In comparison to the Hybrid III 50th percentile male (HIII-50M), the THOR-50M provides improved biofidelity (i.e., a measure of the ATD's ability to mimic a human-like response in a crash) in the thorax, shoulder, spine, knee-thigh-hip, lower leg, and abdomen, as well as improved kinematic response to a frontal crash. Additionally, the THOR-50M allows for multipoint deflection measurements in the thorax and abdomen, upper and lower tibia load cells, and acetabulum load cells, all of which allow for measurement of new injury criteria.

Stage Status: The THOR-50M is currently in Stage 8. NHTSA has an active rulemaking concerning the standardization of the THOR-50M. The NPRM for THOR-50M inclusion in Part 572 was published on September 7, 2023.[31] Additionally, NHTSA is currently considering optional use of the THOR-50M in FMVSS No. 208 (RIN: 2127-AM21).

THOR 5th Percentile Female Frontal ATD (THOR-05F):

The THOR-05F is currently being developed and evaluated by NHTSA. The THOR-05F represents a small adult female and has a seated height of 81.3 cm (32.0 in), approximate standing height of 151 cm (59.4 in), and weight of 49 kg (108.0 lbs). NHTSA has incorporated improved designs resulting from the development of THOR-50M related to the head, neck, thorax, and lower extremities into the design of the THOR-05F. Additionally, the THOR-05F has other improved measurement capabilities over the HIII-05F, including face loads, clavicle loads, thorax displacement, abdominal pressure, acetabulum loads, and ankle displacements and loads. These measurements would permit evaluation of injury types not currently considered. THOR-05F may be considered for use in FMVSS No. 208 and NCAP frontal crash test conditions.

Stage Status: See Appendix B for detailed status of THOR-05F.

WorldSID 50th Percentile Adult Male Side ATD (WorldSID-50M):

NHTSA is considering including the WorldSID-50M in Part 572 and for use in FMVSS No. 214 as an optional test device. The WorldSID-50M represents a mid-sized adult male and has a seated height of 87 cm (34.3 in), an approximate standing height of 175 cm (68.9 in), and a weight of 74 kg (163.1 lbs). The WorldSID-50M offers improved lateral and oblique biofidelity in the thorax when compared to the ES-2re, improved biofidelity in the abdomen and pelvis, as well as the utilization of on-board data acquisition systems and multi-point deflection measurement in the thorax.

[31] https://www.federalregister.gov/documents/2023/09/07/2023-19008/anthropomorphic-test-devices-thor-50th-percentile-adult-male-test-dummy-incorporation-by-reference

Stage Status: The WorldSID-50M is currently in Stage 6. NHTSA is planning to propose including WorldSID-50M in part 572 and as an optional test device in FMVSS No. 214 (RIN: 2127-AM23).

WorldSID-05F:

The WorldSID-05F represents a small adult female and has a seated height of 76.1 cm (30.0 in), approximate standing height of 151 cm (59.4 in), and weight of 48 kg (105.8 lbs). The WorldSID-05F would incorporate all the improved measurement capabilities and internal data acquisition systems of the WorldSID-50M. Potential test modes in which the WorldSID-05F could be used include FMVSS No. 214 and NCAP side impact testing.

Stage Status: The WorldSID-05F is currently in Stage 3 and Stage 4. NHTSA is evaluating the WorldSID-05F's biofidelity, evaluating new thoracic injury prediction instrumentation, and developing documentation.

Large Omnidirectional Child 10-year-old Child ATD (LODC-10YO):

The LODC-10YO is currently under development by NHTSA. The LODC represents a 10-year-old child and has a seated height of 68 cm (26.8 in), approximate standing height of 130 cm (51.2 in), weight of 34.6 kg (76.3 lbs), and is designed to represent both male and female children. The LODC offers a flexible thoracic spine resulting in more accurate head motion and a biofidelic abdomen with pressure sensors for instrumentation. Also, the LODC incorporates biofidelity characteristics derived directly from pediatric biomechanical data, includes omnidirectional instrumentation, and represents improved anthropometry of a 10-year-old child in comparison to the HIII-10YO.

The LODC is intended for evaluating vehicle and booster seats in sled and full vehicle test conditions.

Stage Status: The LODC currently has activities across Stage 3 to Stage 6. NHTSA is building up the inventory of production-level LODCs to the latest design stage by updating internal prototypes and through ongoing contracts with two different ATD manufacturers. Because of extensive prior Stage 5 evaluation of LODC prototypes, Stages 4-6 are expected to be complete for the LODC within a year of having multiple production-level LODCs available for evaluation.

Biofidelic Rear Impact Dummy Mid-Sized Male ATD (BioRID-II):

The BioRID-II is currently under development. The BioRID-II was initially developed in Europe and NHTSA is evaluating its potential use in the U.S. The BioRID-II represents a midsized adult male and has a seated height of 88 cm (34.6 in), an approximate standing height of 168 cm (66.1 in), and a weight of 78 kg (172.0). BioRID-II is the first dummy to have a continuous, articulated spine that can be instrumented in such a way that allows for the measurement of intervertebral rotations of the cervical spine. Hence, these measurements provide improved assessment of whiplash injury when compared to the HIII-50M. Potential applications of the BioRID-II include testing for FMVSS No. 202a "Head Restraints" and/or FMVSS No. 207 "Seating Systems."

Stage Status: The BioRID-II is currently in Stage 4 and Stage 5. NHTSA is evaluating the biofidelity of the BioRID-II, developing injury criteria, and developing documentation. Completion of documentation to support agency decisions is anticipated by 2025.

Appendix B: THOR-05F Stage Completion Status

The content below provides a detailed summary of the completed, current, and planned stages for the THOR-05F ATD.

Stage 1: *THOR-05F Status* – ***Complete***. The THOR-05F was introduced conceptually as a 5th female version of the THOR 50th male ATD in the early 2000s[32] with a single prototype developed/delivered in the mid-2000s, which was used in limited testing.[33] As the development of the THOR 50th male progressed to Stage 5, NHTSA decided to pursue the re-development of a THOR 5th percentile female ATD in 2013 given its projected biofidelity and instrumentation improvements as compared to the Hybrid III 5th percentile female.

Stage 2: *THOR-05F Status* – ***Complete***. In 2013 NHTSA began re-specifying the desired characteristics of the THOR 5th female. These efforts included an assessment of anthropometry targets as well as the development of biofidelity specifications and a drawing package which were published at Regulations.gov[34]. These technical documents were used to support Stage 3.

Stage 3: T*HOR-05F Status* – ***Complete***. NHTSA issued a contract in fiscal year (FY) 2015 for the design, development, build, and biofidelity assessment of three new prototype THOR-05F ATDs. Three prototype ATDs were received by NHTSA in 2018. This contract included subcontracting to academic institutions to assess biofidelity of the prototype ATDs.

Stage 4: *THOR-05F Status* - ***In process***. NHTSA has undertaken over four years of efforts starting upon receipt of three prototype ATDs in 2018. These efforts include inspection, testing, and evaluating the durability and biofidelity of the THOR-05F. Significant findings/issues include the identification of thorax durability concerns in rear seat, standard seat belt 35-mph sled testing. To address these concerns, NHTSA awarded a contract for the redesign of the thorax to prevent the permanent rib deformation observed in the rear seat sled tests. NHTSA anticipates completion of Stage 4 for THOR-05F in 2023.

Stage 5: *THOR-05F Status* - ***In process***. Testing under Stage 5 has been done in parallel to items under Stage 4 and 6. NHTSA completed a limited series of FMVSS No. 208 frontal crash tests with the THOR-05F to assess its performance/response/durability in those conditions. More testing is planned pending results of durability items noted in Stage 4.

More testing is needed to complete "fleet" tests to understand the implications for potential agency decisions. The fleet tests also support the estimates of societal benefits and evaluation of the need for safety countermeasures.

Stage 6: *THOR-05F Status* - ***In process***. Agency decision is pending further testing and confidence in ATD design and performance as well as associated technical documentation.

A summary of Stage 6 THOR-05F efforts is provided below.

> *Injury criteria*: Research targeting the collection of female cadaver specific injury/response data to be applied on the THOR 5th began in 2016. These efforts continue and include in-process injury

[32] https://www-esv.nhtsa.dot.gov/Proceedings/18/18ESV-000421.pdf
[33] https://www-esv.nhtsa.dot.gov/Proceedings/21/09-0546.pdf
[34] https://www.regulations.gov/docket/NHTSA-2019-0107/document

criteria/biofidelity research tasks for the neck, thorax, abdomen, knee-thigh-hip, leg, and foot/ankle. Current task order contracts supporting injury criteria development run through at least calendar year (CY) 2024. ***Timing***: Draft injury criteria report/provisional injury targets planned for CY 2024.

Qualification repeatability and reproducibility (R&R): Efforts to document qualification R&R for THOR-05F began upon receipt of the initial three prototype ATDs in 2018. These efforts continue today and, in-part, will be done once all design/durability updates are complete (e.g., thorax durability effort noted above). The R&R testing is used to define performance specifications included, along with the test procedures, in the Qualification Procedures and Specifications document. ***Timing***: Target completion of draft documentation in CY 2024.

Procedures for Assembly, Disassembly, and Inspection (PADI): Like qualification R&R, the PADI document will be completed once the ATD design is finalized. ***Timing***: Target completion of draft PADI in CY 2024.

Drawing Package: Will be completed once the ATD design is finalized. ***Timing***: Target completion for drawing package in CY 2024.

Other supporting reports: Durability and an updated biofidelity report will also be completed once the design is complete and corresponding testing has finished. ***Timing***: Target completion in CY 2024.

Key Milestone - Decision to pursue rulemaking / draft notice(s): NHTSA will revisit near-term milestones once durability issues are resolved and draft an outline of planned technical content for Part 572 NPRM that will follow the lead of THOR-50M NPRM regarding content/requirements (see *Risk Mitigation* in Stage 7 regarding how NHTSA could accelerate the publication of an NPRM).

Stage 7: *THOR-05F Status - Not started*. A forecasted date for publication of an NPRM for THOR-05F has been published in the Regulatory Agenda (RIN: 2127-AM56).[35]

Stage 8: *THOR-05F Status - Not started*. To mitigate the risk of a longer timeline to rulemaking, NHTSA will consider public comments received for the THOR-50M NPRM and adjust research plans to address any significant issues that would also apply to THOR-05F.

Stage 9: *THOR-05F Status - Not started*.

[35] https://www.reginfo.gov/public/do/eAgendaViewRule?pubId=202304&RIN=2127-AM56

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