

Road vehicles — Design and performance specifications for the WorldSID 50th percentile male side-impact dummy —

Part 1: Terminology and rationale

ICS 43.020

National foreword

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INTERNATIONAL STANDARD

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Road vehicles — Design and performance specifications for the WorldSID 50th percentile male side-impact dummy —

Part 1: Terminology and rationale

*Véhicules routiers — Conception et spécifications de performance pour
le mannequin mondial (WorldSID), 50^e percentile homme, de choc
latéral —*

Partie 1: Terminologie et raisonnement



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15830-1 was prepared by Technical Committee ISO/TC 22, *Road vehicles*, Subcommittee SC 12, *Passive safety crash protection systems*.

ISO 15830 consists of the following parts, under the general title *Road vehicles — Design and performance specifications for the WorldSID 50th percentile male side impact dummy*:

- *Part 1: Terminology and rationale*
- *Part 2: Mechanical subsystems*
- *Part 3: Electronic subsystems*
- *Part 4: User's manual*

Introduction

This first edition of ISO 15830 (all parts) has been prepared on the basis of the existing design, specifications and performance of the WorldSID 50th percentile adult male (PAM) side impact dummy. The purpose of ISO 15830 is to document the design and specifications of this side impact dummy in a form suitable and intended for worldwide regulatory use.

In 1997, ISO/TC22/SC12 initiated the WorldSID 50th PAM dummy development, with the aims of defining a global-consensus side impact dummy, having a wider range of human-like anthropometry, biofidelity and injury monitoring capabilities, suitable for regulatory use. Participating in the development were research institutes, dummy and instrumentation manufacturers, governments, and vehicle manufacturers from around the world.

With regard to potential regulatory, consumer information or research, and development use of ISO 15830, users will need to identify which of the permissive (i.e. optional) sensors and other elements defined in Part 3 are to be used in a given application.

In order to apply ISO 15830 properly, it is important that all four parts be used together.

Road vehicles — Design and performance specifications for the WorldSID 50th percentile male side-impact dummy —

Part 1: Terminology and rationale

1 Scope

This part of ISO 15830 provides the definitions, symbols and rationale used in all parts of this International Standard for the WorldSID 50th percentile side impact dummy, a standard anthropomorphic dummy for side impact testing of road vehicles. It is applicable to impact tests involving:

- passenger vehicles of category M1 and goods vehicles of category N1,
- impacts to the side of the vehicle structure, and
- impact tests involving use of an anthropomorphic dummy as a human surrogate for purpose of evaluating compliance with vehicle safety standards.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1207, *Slotted cheese head screws — Product grade A*

ISO 4026, *Hexagon socket set screws with flat point*

ISO 4027, *Hexagon socket set screws with cone point*

ISO 4029, *Hexagon socket set screws with cup point*

ISO 4762, *Hexagon socket head cap screws*

ISO 6487, *Road vehicles — Measurement techniques in impact tests — Instrumentation*

ISO 7379, *Hexagon socket head shoulder screws*

ISO 7380, *Hexagon socket button head screws*

ISO/TR 9790:1999, *Road vehicles — Anthropomorphic side impact dummy — Lateral impact response requirements to assess the biofidelity of the dummy*

ISO 10642, *Hexagon socket countersunk head screws*

SAE J211-1:2003, *Instrumentation for impact test – Part 1: Electronic instrumentation*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

1-to-2-G-setting

joint friction setting which will support the weight of a horizontally extended limb segment but will not support twice the limb segment weight

3.2

abdomen rib

lowest two ribs of the six mechanical ribs in the WorldSID dummy

3.3

aluminium honeycomb

manufactured material comprising multi-layered bonded sheets of aluminium bent or corrugated in a rib pattern, in which there is an internal pattern of hexagonal cylindrical spaces, and which is used in this International Standard as an energy-absorbing element in certification tests

3.4

capacity

maximum force or moment which can be measured by a load cell without causing load cell damage

3.5

certification

process by which the relevant dummy component or whole dummy is verified and documented to meet the specifications

3.6

cheese screw

slotted button head screw, also referred to as a slotted cheese head screw as defined by ISO 1207

3.7

docking station

data recorder connection point inside the dummy which allows the recorder to be conveniently disconnected from the sensors

3.8

full arm

assembly of the WorldSID dummy comprising the articulated upper arm and lower arm including hand

3.9

frontal

forward facing or anterior surfaces of the dummy, when it is in a standing posture

3.10

H-point

a point on the outer surface of the dummy on an imaginary line which passes through the left and right hip ball centres

3.11

H-point tool

device which can be inserted into index holes in the dummy pelvis, which provides an external surface for indicating the orientation of the pelvis, and an imaginary line connecting the left and right hip ball joint centres

3.12

half arm

assembly of the WorldSID dummy comprising dedicated upper arm components which are different from the components of the full arm

3.13**head form**

mechanical device with the same mass and I_{xx} inertia as the WorldSID head, used for lateral neck certification tests

3.14**infrared telescoping rod for assessment of chest compression****IR-TRACC**

sensor for deflection measurements

3.15**lower leg**

portion of the lower extremity between the knee and the ankle

3.16**mass replacement**

non-electronic component which is substituted for a given dummy electronic component, which has the same mass as the given electronic component and which does not act as a structural component of the dummy (e.g. an accelerometer)

3.17**rigid seat**

specialized seat with defined seat bottom and seat back angles used to position the dummy for impact testing

3.18**shoulder rib**

upper-most rib of the six mechanical ribs in the WorldSID dummy

3.19**structural replacement**

non-electronic component which is substituted for a given dummy electronic component (e.g. a load cell), which has the same mass as the given component and which also acts as a structural component of the dummy

3.20**thoracic rib**

second, third and fourth upper-most ribs of the six mechanical ribs in the WorldSID dummy

3.21**T1**

location corresponding to the first thoracic vertebra in a human

3.22**T4**

location corresponding to the fourth thoracic vertebra in a human

3.23**T12**

location corresponding to the twelfth thoracic vertebra in a human

3.24**tilt sensor**

sensor internal to the dummy which transduces the two orientation angles of the respective body region relative to gravity

3.25**universal**

capable of being mounted at several different locations on the dummy

3.26

upper leg

that portion of the lower extremity between the knee and the hip ball

3.27

W50-

prefix denoting WorldSID 50th percentile adult male dummy part or drawing number

3.28

WorldSID

anthropometric side impact dummy intended to be used by vehicle manufacturers and all interested parties in the passive safety field to improve occupant protection and in regulatory and consumer information testing in various regions of the world

4 Symbols, subscripts and abbreviated terms

4.1 Symbols

See Table 1.

Table 1 — Symbols and their meanings

Symbol	Meaning
a	Linear acceleration
F	Force
G	Acceleration due to gravity (9,81 m/s ²)
M	Moment
β	Angular displacement of the head form
δ	Deflection
θ	Angular displacement
φ	Rotation
x	Coordinate in accordance with ISO 6487 or SAE J211-1
y	Coordinate in accordance with ISO 6487 or SAE J211-1
z	Coordinate in accordance with ISO 6487 or SAE J211-1

4.2 Subscripts

See Table 2.

Table 2 — Subscripts and their meanings

Symbol	Meaning
F	Forward
H	Head
R	Rearward
x, y, z	Coordinate system : In the x, y or z direction; about the x, y or z axis where x, y or z are in accordance with ISO 6487 or SAE J211-1

4.3 Abbreviated terms

See Table 3.

Table 3 — Abbreviated terms

Abbreviation	Meaning
AMVO	Anthropometry for Motor Vehicle Occupants dataset (established by UMTRI)
A-P	Anterior-posterior
ASIS	Anterior superior iliac spine
ASPECT	Automotive Seat and Package Evaluation and Comparison Tools (a Society of Automotive Engineers cooperative research program)
ATD	Anthropomorphic test device
BHCS	Button head cap screw, also referred to as a hexagon socket button head screw as defined by ISO 7380
CG	Centre of gravity
CPSS	Cone point set screw, also referred to as a hexagon socket set screw with cone point as defined by ISO 4027
CPSSS	Cone point socket set screw as defined by ISO 4027
CPNT	Cone point nylon tip
DAS	Data acquisition system
FHCS	Flat head cap screw, also referred to as a hexagon socket countersunk head screw as defined by ISO 10642
FTSS	First Technology Safety Systems
IHRA	International Harmonization Research Activities
ISO	International Organization for Standardization
LHSHCS	Low head socket head cap screw
MDB	Movable deformable barrier
NM	Not measured

Abbreviation	Meaning
NTSS	Nylon tip set screw
OC	Occipital condyle
PAM	Percentile adult male
PC	Personal computer
R-L	Right-left
SHCS	Socket head cap screw, also referred to as a hexagon socket head cap screw as defined by ISO 4762
SHSS	Socket head shoulder screw, also referred to as a hexagon socket head shoulder screw as defined by ISO 7379
SI	Sacro-iliac
SSCP	Set screw with cup point, also referred to as a hexagon socket set screw with cup point as defined by ISO 4029
SSFP	Set screw with flat point, also referred to as a hexagon socket set screw with flat point as defined by ISO 4026
SSHDP	Set screw with half dog point, as defined by ISO 4026
SSNT	Set screw with nylon tip
UMTRI	University of Michigan Transportation Research Institute

Annex A (informative)

Rationale regarding background and goals for WorldSID

NOTE All references cited in Annex A are listed in the Bibliography.

A.1 Historical background

A.1.1 General

In November 1997, the WorldSID Task Group was formed under the auspices of the International Organization for Standardization (ISO) TC22/SC12/WG5 - Anthropomorphic Test Devices. Document ISO/TC22/SC12/WG5/N512 (see Annex C) established the composition and responsibilities of the Task Group. The Task Group's purpose was to develop a unique, technologically advanced side impact dummy which would have greater biofidelity and which would replace the variety of side impact dummies used in regulation and in other testing. It was with this double objective of developing an advanced and globally harmonized dummy that the WorldSID Task Group was formed, including a Tri-Chair representing each of the Americas, Europe and Asia-Pacific regions, and experts from more than 10 countries including Australia, Canada, France, Germany, Japan, The Netherlands, Sweden, United Kingdom and United States of America. The members comprised participants from vehicle manufacturers, governmental organizations, research institutes, test laboratories and dummy and instrumentation manufacturers from around the world.

Worldwide vehicle manufacturers and governmental bodies sponsored the WorldSID's development. A design team of worldwide dummy manufacturers, instrumentation manufacturers and research organizations was formed to design, develop and fabricate the prototype. Twenty-four Task Group meetings were held in order to coordinate the definition, design, development and evaluation of the dummy, as well as to develop a working draft standard that was submitted to Working Group 5 in October 2003. During the pre-production stage, more than 12 separate organizations from around the world conducted testing and evaluations of the dummy in order to assess its biofidelity, durability, repeatability, reproducibility and other aspects of performance. Regulation-ready documentation was prepared in the form of ISO 15830, which is available to the relevant regulatory and consumer information bodies worldwide.

The resulting WorldSID 50th percentile adult male is a new, advanced, global consensus, side impact dummy. It has an overall biofidelity classification of 7,6 ("good") using the ISO/TR 9790 biofidelity rating scale. It is planned to be the basis for the future development of a harmonized side impact dummy family. The WorldSID 50th percentile adult male has a mass of 77,3 kg, a theoretical standing height of 1753 mm and a seated height of 911 mm. Almost every body region involves a new, innovative design, setting the WorldSID apart from all existing side impact dummies. It can accommodate up to 176 optional standardized sensors and associated cabling, and up to 192 channels of recording with an optional in-dummy data acquisition system (DAS).

A.1.2 Need for an International Standard side impact dummy

As of October 2003, five other mid-sized male side impact dummies were available for regulatory, consumer information and development use. They are the USDOT-SID dummy, which is utilized in the United States side impact protection regulation^[33]; the EuroSID-1 dummy, which is regulated in a European standard^[34]; the ES-2 dummy, which was being considered for European-Japan regulatory use under the UN/ECE 1958 Agreement; the Hybrid III-SID dummy which is utilized in the United States side impact protection regulation FMVSS-201; and the BioSID dummy, which is available for developmental purposes. None of these dummies has "good" biofidelity (i.e., they are all less than "6,5" rating using the ISO/TR 9790 biofidelity rating scale). The five dummies are structurally different, and have different instrumentation capabilities and associated injury assessment criteria. Because of these differences, as well as the differences in the associated test procedures, these dummies typically provide different design direction in the vehicle development process.

This results in substantially different vehicle designs with regard to side impact protection in the different world regions, despite the similarity in occupant protection needs among the regions.

The existing dummies are less human-like, and cannot be instrumented for all the body regions of importance in side impact protection. This means that they have limited effectiveness as tools for improving occupant protection.

In addition, the total costs to a vehicle manufacturer, and therefore to consumers, of developing different side protection systems for different regions is higher than a harmonized system.

Overall, with the existing diversity of dummies, the benefits in terms of occupant protection are lower, and the costs higher, than what would be the case if a more human-like side impact dummy was adopted on a worldwide basis.

A.1.3 Benefits and economic impact of an International Standard side impact dummy

A more human-like side impact dummy, accepted via consensus among the participating regions by means of an International Standard, along with harmonized vehicle side impact test procedures, will have significant benefits in terms of more realistic (and therefore more effective) occupant protection; as well as in reduced costs of side impact protection system development.

With regard to benefits, it is self-evident that a more advanced, human-like side impact dummy would result in vehicle side impact protection systems that would be more effective for human occupants, and would be less likely to produce harmful designs, which in principle can result from dummies that are either less human-like or unable to monitor for injuries to some body regions.

With regard to costs, it is also self-evident that vehicle manufacturers could eliminate the additional, wasteful efforts needed to develop vehicles to pass different regulatory tests, with different dummies, when they are to be sold in several markets. This process is costly for consumers and has no benefits for passive safety.

For these reasons, most of the major industrial nations, including members of the European Union, Canada, Japan and the United States, signed the *"Agreement concerning the establishing of global technical regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles,"* (1998) also referred to as the 1998 Global Agreement. This treaty implemented objectives and methods for proposing and developing within the forum of UN/ECE/TRANS/WP29 global technical regulations (GTR), which contracting nations or groups of nations would have the option to adopt as part of their domestic rulemaking processes. For similar reasons, to further support development of internationally harmonized test procedures and criteria, an International Harmonized Research Activity (IHRA) was established during the 15th International Technical Conference on the Enhanced Safety of Vehicles (ESV) held in Melbourne, Australia in 1996.

In summary, the WorldSID would be expected to have substantial benefits for occupant protection, and would reduce total development costs.

A.1.4 Survey of and general differences from previous side impact dummies

As mentioned in A.1.2, as of October 2003 there were five mid-sized male side impact dummies, as well as some variations thereto, available for regulatory and development use. The five dummies have different levels of biofidelity. The USDOT-SID, EuroSID-1, ES-2 and BioSID dummies have each been rated using the ISO biofidelity scale that provides classifications, as shown in Table A.1^[13]. These classifications quantify how closely the dummy dynamic response matches those of a sample of human subjects, for each body region and for all body regions. The USDOT-SID has a ISO biofidelity classification of "unacceptable", the EuroSID-1 and ES-2 have a classification of "marginal" and the BioSID has a classification of "fair."

Table A.1 — ISO biofidelity rating scale

Excellent	> 8,6 to 10
Good	> 6,5 to 8,6
Fair	> 4,4 to 6,5
Marginal	> 2,6 to 4,4
Unacceptable	0 to 2,6

As reported by Byrnes, K., et al.^[3], the US OSRP (Occupant Safety Research Partnership) conducted a series of ISO/TR 9790 tests in order to compare the biofidelity ratings of the current 50th percentile male side impact dummies USDOT-SID, EuroSID-1, ES-2 BioSID and the WorldSID. Even if not all ISO/TR 9790 tests were carried out identically with each dummy (as described in, for example, Appendix G of ^[13]), the WorldSID was the only dummy to obtain a “good” rating on the ISO biofidelity scale.

As shown in Table A.2, the WorldSID achieved the best overall dummy rating and also the best single body region ratings for the head, thorax, abdomen and pelvis.

Table A.2 — Biofidelity comparison of side impact dummies

	Biofidelity rating						
	Head	Neck	Shoulder	Thorax	Abdomen	Pelvis	Overall
WorldSID production version	10,0	5,6	7,1	8,3	7,8	6,1	7,6
BioSID	6,7	6,7	7,3	6,3	3,8	4,0	5,7
ES-2	5,0	4,4	5,3	5,2	2,6	5,3	4,6
EuroSID-1	5,0	7,8	7,3	5,4	0,9	1,5	4,4
USDOT-SID	0,0	2,5	0,0	3,1	4,4	2,5	2,3

Independently, the US/NHTSA (National Highway Traffic Safety Administration) evaluated the WorldSID prototype (unrevised version) together with two other side impact dummies, the ES-2 and the Hybrid III-SID to a newly developed biofidelity ranking system called Bio Rank System, as reported by Rhule, H., et al.^[20].

This Bio Rank System quantifies the ability of a dummy to load a sled wall as a cadaver does (External Biofidelity) and the ability of a dummy to replicate those cadaver responses that best predict injury potential (Internal Biofidelity). The ranking is based on the ratio of the cumulative variance of the dummy response relative to the mean cadaver response and the cumulative variance of the mean cadaver response relative to the mean plus one standard deviation. That ratio expresses how well a dummy duplicates a cadaver response. Contrary to the ISO rating system, the lower the rating value the better the biofidelity.

Although still under development and not in use by the international community, the data presented by Rhule, et al., indicate that this assessment system also showed the WorldSID prototype to have the best ranking out of the three tested dummies.

In summary, compared with other, contemporary mid-sized adult male side impact dummies, the WorldSID overall ratings are better than all others. It achieves by far the best overall rating, and was the only side impact dummy as of October 2003 with an overall biofidelity rating of “good.”

A.1.5 Summary of WorldSID development process

The following summarizes some of the milestones in the WorldSID project, in order to describe the international development and consensus process:

- November 1997: WorldSID Task Group (TG) established by ISO/TC22/SC12, reporting to Working Group 5.
- April to October 1998: draft documents were circulated within the TG as regional contributions to the definition of design and performance requirements for WorldSID.
- February 1999: the WorldSID Task Group and project manager circulated the “Request for Proposals-WorldSID Design and Build” internationally, which included a draft design baseline.
- March 1999: the Task Group made a first selection of WorldSID body region and instrumentation concepts, on the basis of all responses to the Request for Proposal.
- September 1999: the Task Group signed off the WorldSID Design Baseline (document TG N60 Rev 2). This document includes design and performance specifications for the WorldSID as established by consensus of the Task Group during the period October 1998 to September 1999, and defines the guidelines for designing, building and evaluating the first prototype dummy.
- February 2000: at the 12th TG meeting, the Design Team (DT) presented a first full assembly 3D WorldSID concept, based on updated body part and instrumentation concepts. The TG was given an illustration of the full assembly WorldSID (document TG N105, February 2000). Using the Design Brief (TG N60Rev2) as a reference, the Design Team developed as much detail as possible on the specifications for design and performance of the WorldSID. Any deviations from specifications were detailed and rationales for these deviations were provided.
- December 2000: A prototype dummy was completed, and sent to Australia for a first round of vehicle and biofidelity tests by the Australian government.
- January 2001 to February 2003: A series of iterative testing and design revisions were conducted on the prototype dummy, resulting in design changes and performance improvements to all body regions of the dummy.
- March 2003 to January 2004: Delivery, testing and evaluation of 11 pre-production dummies by numerous parties in the three regions. Beginning in March 2003, the pre-production dummies were evaluated in biomechanical tests, and also in a multitude of sled, crash and verification tests throughout the world.
- October 2003: Delivery of a working draft of ISO 15830 to Working Group 5.
- March 2004 and after (planned): Based on the biofidelity, repeatability and durability results, the completion of the side impact dummy with the highest level of biofidelity in the world, the WorldSID, is planned to be ready for the release into the public domain. Release of final production drawings and specifications into the public domain, and balloting of the committee draft, and then the draft, International Standard.

Organizationally, at every stage, the TG attempted to include all interested parties involved in the passive safety field, and to this end, three regional groups for Europe, Asia-Pacific and the Americas, were created to facilitate the participation of any interested parties on a worldwide basis. The Task Group brought together delegations from the three regions on a regular basis. The project was financed by contributions from all three of the regions, as further described below. A project manager was contracted to co-ordinate the development activities and to liaise between the Task Group and the Design Team. The Task Group contracted with Design Team members, comprising dummy manufacturers, instrumentation manufacturers and members of the European Commission (EC)-sponsored SID-2000 project consortium, to carry out the design and development work.

The vehicle manufacturers in the United States, Japan and the European Union made large direct contributions to funding through their regional industry organizations: OSRP, JAMA and ACEA respectively. The European Commission also made a significant contribution through the participation in the development of the dummy of the SID-2000 Consortium. Contributions from Transport Canada, the Australian Department of Transport and Regional Services, the US National Highway Transportation and Safety Administration and the European Commission-supported SIBER consortium contributed to the funding of the WorldSID prototype evaluation testing. All costs related to the participation of Task Group and Regional Advisory Group members were met by the individual participating organizations.

A.2 Technical targets for the WorldSID

A.2.1 General

The WorldSID Task Group, with inputs from all members as well as the Design Team, developed a comprehensive set of technical targets in the following categories:

- Functional description and interface references
 - Functional description
 - Interface references
- Loading conditions and interactions
- Anthropometry
- Biofidelity
- Instrumentation
- Repeatability and reproducibility
- Durability
- Sensitivity
- Handling
- Certification
- Miscellaneous

Detailed targets in each of these areas were identified for the overall dummy, and for each of the body regions:

- Head
- Neck
- Shoulder-thorax-abdomen
- Full arms
- Half arms
- Lumbar spine

- Pelvis
- Upper legs
- Lower legs
- Clothing

In addition, targets for internal electronic measurement components were identified, including those for:

- Accelerometers
- Load cells
- Displacement transducers
- Tilt sensors, to facilitate dummy positioning
- In-dummy data acquisition system

During the development, the highest priority among these targets was given to the goal of matching the biofidelity (i.e., human dynamic response) targets specified in ISO/TR 9790^[13]. The target performance was that a rating of “good” to “excellent” be achieved, on the biofidelity rating scale contained in ISO/TR 9790, for all segments of the dummy, and for the overall dummy. In addition, alternative biofidelity targets were being developed by the International Harmonized Research Activity - Biomechanics Working Group. Another high priority was that if these were available during the WorldSID development period, they would be also applied. The latter were still under development at the date of this writing.

The WorldSID Task Group reviewed all of the currently existing side impact dummies to determine what functions, features and other needs should be incorporated into the new WorldSID dummy and what improvements were required. The group also reviewed various proposals and ideas from worldwide dummy and instrumentation manufacturers and research organizations. As described in A.1.5, an international Design Team was formed to develop these new concepts and integrate them with existing desirable features into a new, advanced side impact dummy. The majority of the dummy consists of new design concepts, with the exception of the neck, which is mainly from the ES-2 dummy (all parts except for the neck buffers).

The Task Group also assembled a list of specifications for the WorldSID dummy. This list consisted of general specifications for the full dummy assembly and specific specifications for the various body regions. One of the general targets for the dummy was that it should be a left-right symmetrical design. The Task Group decided that this was necessary firstly, because humans are symmetric, and also because future uses of the dummy are unknown. For example, in the future the dummy may need to measure occupant-to-occupant interaction in a side impact test. If this were required, the dummy would have to be capable of being instrumented simultaneously on both sides so that it could measure the impact from the striking vehicle and the impact from the adjacent occupant.

In addition, because of the unknown nature of future testing needs, it was desired that the dummy produce reasonable data for ± 30 degrees in the horizontal plane and ± 10 degrees in the vertical plane. This is to ensure that the dummy does not bind in an off-axis loading situation.

It was also desired that the dummy be capable of using an in-dummy data acquisition system (DAS). This was because of the increasing number of potential channels of interest being specified for injury evaluation purposes. The large number of desirable sensors would produce a large bundle of cables that conventionally would need to be attached to an in-vehicle DAS. This would make it difficult to properly position the dummy. So, the Task Group concluded that it was necessary to offer an optional in-dummy DAS. The WorldSID dummy has over 200 possible data channels. The user, of course, would choose only the appropriate channels for a given testing scenario.

A.2.2 Functional description

In general terms, the WorldSID was to be designed for the evaluation of vehicle occupant protection in the event of a lateral collision. In addition, it is expected that because of improved characteristics (e.g., improved biofidelity), the WorldSID will replace existing side impact dummies. The dummy therefore was to accommodate:

- Several types of standardized test procedures to assess side impact car occupant protection in full vehicle collisions. This includes existing procedures as well as future harmonized procedures of regulatory bodies, as well as procedures used by consumer information organizations to compare vehicle performance.
- Development type testing (standard and non-standard) as conducted by the OEM's and their suppliers to assess and improve performance of restraint systems, vehicle interiors, vehicle structures, etc.
- Research type testing to enhance the knowledge base of side impact vehicle and occupant behavior, through accident reconstructions, component tests, biomechanical tests, etc.

In all these test conditions, the WorldSID was to have improved dynamic behavior over existing dummies, have improved measurement capabilities to allow assessment according to most established and evolving injury criteria, and to be easier to handle.

To accommodate the different test conditions, the WorldSID was to be designed in two configurations: one incorporating instrumented full-arms and one incorporating non-instrumented half-arms. The WorldSID development therefore breaks down in the following components (responsible Design Team member is given in parentheses):

- Head (SID-2000), representing the human head and designed to exhibit multi-directional biofidelity considering its large variety of contact and non-contact loading conditions.
- Neck (SID-2000), representing the human cervical spine and primarily designed to assure proper head kinematics without concern for unrealistic restraint interactions as observed with some existing dummies.
- Shoulders/thorax/abdomen assembly (FTSS, SID-2000), representing the human upper torso, with improved biofidelity over existing dummies, and capable of handling off-axis loading without compromising durability, repeatability and reproducibility.
- Full-arms (Denton), representing the human upper arms, elbows, lower arms, wrists and hands, designed primarily for the purpose of airbag interaction assessments.
- Half-arms (FTSS), representing the human upper arms only, designed for full vehicle testing in which the use of full-arms may lead to reduced test-to-test repeatability.
- Lumbar spine (FTSS), representing the human lumbar area, designed to better represent the coupling between upper and lower torso and to allow changes in initial (pre-test) posture according to seat and vehicle design.
- Pelvis (SID-2000), representing the human lower torso, designed with improved biofidelity over existing dummies, and capable of handling off-axis loading without compromising durability, repeatability and reproducibility.
- Upper legs (Denton), representing the human upper legs and knees, designed with integrated instrumentation.
- Lower legs (ASTC/GESAC), representing the human lower legs, ankles and feet (including shoe), designed with integrated instrumentation.

- Clothing (FTSS), extending over the complete torso and parts of the extremities to simulate clothing, but also some human skin/flesh.
- In-dummy data acquisition system (DTS), which accommodates at least 64 channels. Integrated wiring throughout the dummy is part of this task.
- Accelerometers (Endevco), including linear and angular accelerometers throughout the dummy and dedicated tilt sensors in the head, thorax and pelvis for pre-test positioning.
- Load cells (Denton), throughout the dummy and designed as structural components. Structural replacements for all load cells will be provided.

A.2.3 Interface references

The complete WorldSID design and fabrication was contracted to a Design Team that operated under mutual confidentiality but also mutual restriction of design information. This meant that not until approval and release into the public domain of the WorldSID drawings and specifications by the Task Group, would a non-generating party within or outside the Design Team have access to design information from a generating party.

This, obviously, was not the case for the interfaces between various components of the dummy, which were generated by Design Team members responsible for components meeting at a specific interface. Therefore, much emphasis in the design stage was put in the definition of interfaces between various components of the dummy. In addition, good definition of interfaces between the various components was essential to ensure proper assembly and functionality.

Where possible, interface references were based on anthropometry data (anatomical landmarks, joint locations, etc.).

Further details of the specific body region functional requirements and interface reference needs were presented in the Design Brief^[32].

A.2.4 Loading conditions and interaction needs

One requirement for WorldSID was that it function properly within the loading conditions specified by existing and future harmonized test procedures, such as those under development within IHRA. This was not to be restricted to the test procedures themselves, which include MDB type side impact tests, pole tests and component tests, but also tests to enable development of vehicles, vehicle components and restraints. It was beyond the scope of the Design Brief to attempt to quantify every loading condition the dummy could be subjected to, however, several requirements involved specifications of minimum responses the WorldSID should be able to withstand or attain.

Further details of the specific body region loading conditions and interaction needs were presented in the Design Brief^[32].

A.2.5 Anthropometry needs

A.2.5.1 General

The WorldSID represents a mid-sized adult male vehicle occupant. Several anthropometry data sources were studied and compared with data from studies on anthropometry of different populations around the world. In September 1999, the WorldSID Task Group decided to accept the AMVO dataset for a 50th percentile male (Robbins, D.H., et al.^[21]). This dataset describes many anthropometry details of a mid-sized adult male in an automotive posture. Included are a 3D surface description, almost 150 anatomical reference points (including joint centres), definitions of segments (head, neck, etc.), and derivation of inertial properties of these segments. The automotive posture as represented by the AMVO dataset is defined as the design reference posture for the dummy.

Communications with UMTRI revealed that some corrections had to be made since the first release of this dataset, specifically with respect to the H-point definition (yet unpublished information from the ASPECT development). FTSS corrected the dataset and created a 3D stickman diagram (lines connecting the joint centres) within the outer shell definition and anatomical landmarks. The Design Team used these as references for the WorldSID design. A detailed description of the anthropometry needs is given in Moss, S. et al.^[17].

A.2.5.2 Overall landmarks

The anthropometric landmark targets for WorldSID are specified in Table A.3.

Table A.3 — Landmarks

Landmark	Description	x mm	y mm	z mm
	vertebral column			
7	C7	-264	0	499,4
8	T4	-291	0	390,4
10	T12	-244	0	156,4
12	L5	-172	0	23,4
	pelvis			
27	iliocristale	-78	±161	103,4
28	anterior superior iliac spine (l,r)	-23	±116	93,4
29	pubic symphysis	53	0	51,4
31	throchanterion (skeletal reconstruction) (l,r)	22	±203	-9,6
32	h-point	0	±83,5	0
	shoulder			
35	greater tubercle humerus (l,r)	Not specified	±218	Not specified
	joint centres			
54	head/neck	-194	0	598,4
55	c7/t1	-191	0	479,4
58	t12/l1	-175	0	175,4
60	l5/s1	-89	0	39
61	sternoclavicular	-143	±43	443,4
62	claviscapular	-228	±168	437,4
63	glenohumeral	-184	±173	403,4
64	elbow	38	±208	211,4
65	wrist	230	±158	403,4
66	hip (h-point)	0	±83,5	0
67	knee	408	±138	146,4
68	ankle	686	±94	-158,6
	estimated segment centres of gravity			
79	head	-177	0	656,4

A.2.5.3 Ranges of motion

The ranges of motion are based on several sources. Shoulder flexion, extension, abduction and adduction ranges are based upon estimates of what was to be necessary for initial positioning of the arm and motion without binding as presented in WorldSID Task Group meetings. Shoulder lateral and medial angular displacement ranges are from attachment I of the January 13, 1998 minutes of the SAE Arm-Airbag Interaction Task Group of the Human Biomechanics and Simulation Standards Committee. The elbow flexion and extension ranges match those of the SAE 5th percentile female instrumented arm. The flexion range is the maximum practical mechanical range. The wrist range of motion was provided by the University of Virginia Auto Safety Laboratory, compiled from a variety of sources.

- Shoulder flexion: 180° to soft stop
- Shoulder extension: 45° to soft stop
- Shoulder abduction: 100° to soft stop
- Shoulder adduction: 0° to soft stop
- Shoulder lateral angular displacement: 31° to soft stop
- Shoulder medial angular displacement: 91° to soft stop
- Elbow flexion: 135° to soft stop
- Elbow extension: -5° to soft stop
- Wrist pronation/supination: 80° to soft stop
- Wrist flexion/extension: 75° to soft stop
- Wrist abduction: 15° to soft stop
- Wrist adduction: 25° to soft stop

A.2.5.4 Head

Reference for the head anthropometry was the AMVO data set. The target data are specified in Table A.4. The target for the outer geometry of the head was based on the Hybrid-III geometry (Hubbard R., et al.^[45]), since this is a more detailed data set. Facial features from the Hybrid-III (nose, lips, etc.) were to be deleted.

Table A.4 — General head anthropometry reference data (Source: AMVO Data Set)

Parameter	Target	Reference	Remark
Mass	4,14 kg $\pm$ 0,1 kg	AMVO	
Circumference.	570,6 mm $\pm$ 5 mm	AMVO 1983 Study	
Length	197,4 mm $\pm$ 2 mm	AMVO	
Width	158 mm $\pm$ 2 mm	AMVO	Hybrid-III: 155 $\pm$ 5 mm
CG location	177 mm, 0 mm, 656,4 mm (with respect to mid H-point)	Corrected AMVO	WorldSID- α anthropometry

The location of the head centre of gravity was to be indicated on the left and right exterior of the head. The tolerance of the indications were to be $\pm$ 2,0 mm.

The coordinates (x, y, z in mm), with respect to the H-point for the head CG and OC-joint were to be (–177, 0, 656,4) and (–194, 0, 598,4) respectively.

For packaging reasons, an adjustment to change the orientation of the head depending on the dummy's posture inside a vehicle could be incorporated at the head-neck junction but was incorporated into the neck-thorax bracket. An adjustable lower neck bracket allowed proper orientation of the head. The head reference plane was to be marked on the head and served as a reference to level the head (note that the head reference plane in the reference posture of the occupant as defined by the AMVO data set is at an angle of 3,7 degrees with the horizontal plane).

A.2.5.5 Neck

The neck has similar mass and mass distribution to that of the human, as available from the reference AMVO data set. The target data are specified in Table A.5. Coordinates of the OC-joint and C7/T1-joint were to be (–194, 0, 598,4) and (–191, 0, 479,4). A neck shroud prevented unrealistic airbag interactions.

Table A.5 — General neck anthropometry reference data (Source: AMVO Data Set)

Parameter	Target	Reference	Remark
Mass	0,965 ± 0,2 kg		Production tolerance is tighter

At the end of the ranges of motion progressive stiffness were to be built in to prevent overloading.

To allow the head to be oriented over a sufficient range of motion (angular displacement around the y-axis) with the dummy in an automotive position, the neck bracket exhibits an adjustability of at least 10 degrees forward (flexion) and 20 degrees rearward (extension) with respect to the reference posture.

A.2.5.6 Shoulder/thorax/abdomen

The anthropometry landmarks are based on the AMVO and derivative studies. Major design targets are given in Table A.6. The three dimensional surface of the AMVO model was used as the design target for the outside contours of the dummy.

Table A.6 — Segment masses

Segment masses	Target
Shoulder and thorax	23,763 kg
Abdomen	2,365 kg

A.2.5.7 Full arms

The arm was designed with reference to the AMVO anthropometry data set. This included approximate outside flesh contours, pivot-to-pivot lengths, component masses, and approximate centre of gravity locations.

— Pivot lengths:

— Shoulder pivot to elbow pivot length: 295,5 mm

— Elbow pivot to wrist pivot length: 276,1 mm

— Assembly masses: The assembly masses were to be made to match the AMVO data set target of 3,79 kg (1,77 kg upper arm and 2,02 kg lower arm). Precise segmentations were to be established during the design phase.

— Flesh contours:

- Hand flesh contour was to be new since it is a gripping hand. Basic contour was to be from the AMVO data surface model with simplified geometry with the fingers curved into a gripping position. Left and right hands were to be mirror images of each other.
- Lower arm flesh contour was to be based on the AMVO data surface model with simplified geometry.
- Upper arm flesh contour were to be based on the AMVO data surface model with simplified geometry.
- The shoulder was to be covered with flesh by extending the upper arm flesh up over the shoulder structure. The specific method for covering the shoulder with flesh was to be addressed during the design stage.

A.2.5.8 Half arms

The half arm was to be designed to meet the WorldSID anthropometry specifications, with reference to the source anthropometry data defined by the AMVO data set. The flesh contour is derived from the AMVO shell surface model, and approximated to a rectangular section to improve the arm stability during test loading.

The half arm-shoulder joint coincides with that of the full arm and was to be at or very close to the position of the gleno-humeral joint of the anthropometry data set (point 63: -184, $\pm$ 173, 403,4)¹⁾

The mass property target of the half-arm is specified in Table A.7.

Table A.7 — Mass properties of the WorldSID half arm

Parameter (all identical left and right)	Target
Segment Mass (identical left and right)	1,769 kg

A.2.5.9 Lumbar spine

The WorldSID lumbar spine component is defined as the connection between the upper and lower torso, and does not specifically simulate the human skeletal lumbar spine. The WorldSID lumbar spine length was to occupy the space between T12/L1 and L5/S1 according to the WorldSID anthropometry specifications in A.2.5.2.

A.2.5.10 Pelvis

A.2.5.10.1 General

Reference for the pelvis anthropometry is the AMVO data set. In order to define the internal geometry of the pelvis, additional data is used from Reynolds, et al.^[36]

A.2.5.10.2 Overall external dimensions

The external shape of the pelvis is based on the AMVO data set ("shell"), but adjusted to obtain a non-compressed buttock flesh. AMVO has defined the pelvis coordinate system at the H point with the directions of the axes along the vehicle coordinate system. Target data are given in Table A.8.

¹⁾ Coordinates are expressed x, y, z in mm with respect to the dummy reference position in an orthogonal reference axis system at the H-point (0, 0, 0), unless specifically specified otherwise. The designation " $\pm$ " refers to left and right side.

Table A.8 — Target data for pelvis external dimensions

Parameter	Target
Mass (only pelvis ²⁾)	11 kg $\pm$ 0,2 kg
Mass (pelvis + femur heads)	14,5 kg $\pm$ 0,3 kg
Hip breadth	385 mm $\pm$ 8 mm

A.2.5.10.3 Detailed internal dimensions

The internal design of the pelvis was to be primarily based on Reynolds, et al.^[36]. The internal body shape (dummy skeleton) was to not represent the whole human anatomy. Only some important anatomical points were to be represented as well as the overall girdle configuration. Whereas the human pelvis skeleton mass is approximately 1 kg, the dummy uses material with higher density than human bone and was to be instrumented, and was to hence have a larger mass than the human pelvis. This also results in variation of the pelvic inertia.

Based on Reynolds' data, several bone points have been defined with respect to the (corrected) AMVO H-point definition. To achieve this, Reynolds' coordinate system has been rotated over 54° and the origin of the Reynolds' axis has been moved to the H point (see definition of Reynolds coordinate system versus AMVO system in Figure A.1 and Figure A.2). Reynolds' bone markers and AMVO surface markers are shown on Figure A.3, Figure A.4, and Figure A.5.

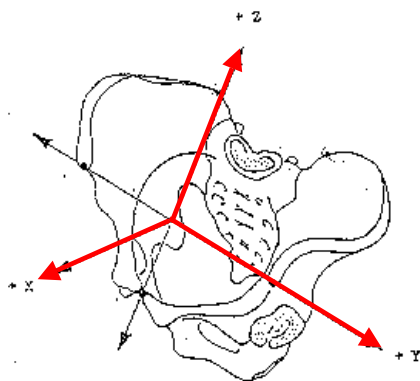


Figure A.1 — Reynolds pelvis co-ordinate system

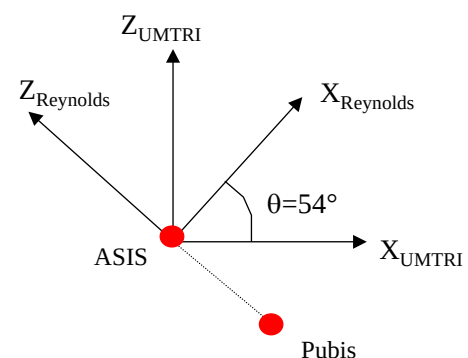


Figure A.2 — Angular shift from AMVO to Reynolds co-ordinate system

²⁾ AMVO report refers to McConville, 1980, who considered pelvis as “originates at the centre of the crotch and passes laterally midway between the anterior superior iliac spine and the trochanter landmarks along the lines of the right and left inguinal ligaments.”