


Rev.: 1.03 Date: 02.01.2018 Page: 1 von 42	Manual iSWACO-ARGUS Testing PAD, HAD & FAD Vehicles up to SAE Level 5	
Document No.: Reference:	DOC171227002 KEP-I000053	



iSWACO-ARGUS

*Efficient Testing of PAD, HAD and FAD Vehicles
on Roads and on Proving Grounds
up to SAE Level 5*


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Commercial-in-Confidence



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DOCUMENT CHANGE RECORD

I = Issued; C = Checked
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1.02	6.3, 6.4	Examples of cognitive vision results for obstacle classification; screenshot about lane change iARGUS-RCS	I/C	29.12.17 02.01.18	JuGr EvH	HD CEO
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DOCUMENT CHECK & APPROVAL REQUIREMENTS

CHECK required	APPROVAL by iMAR required	APPROVAL by Customer required
Yes	No	No

Acronyms of Functions

Industrial/MIL Projects / Industrie- & MIL-Projekte

CEO	Chief Executive Officer (Geschäftsführer)
CUST	Customer (Kunde)
DE	Design Engineer / Development Engineer (Entwicklungsingenieur)
DMS	Director Marketing & Sales
HD	Head of Development (Entwicklungsleiter)
PJM	Project Manager (Projektleiter)
PM	Production Manager (Fertigungsleiter)
QA	Quality Assurance (Qualitätssicherung)
QM	Quality Manager (Qualitätsmanagementbeauftragter)

Aviation & Space Projects / Luft- und Raumfahrtprojekte

AM	Accountable Manager
CUST	Customer (Kunde)
DE	Design Engineer / Development Engineer (Entwicklungsingenieur)
HD	Head of Design (Entwicklungsleiter)
HoA	Head of Office of Airworthiness (Leiter Musterprüfleitstelle)
HoD	Head of Design Organisation
PJM	Project Manager (Projektleiter)
PM	Production Manager (Fertigungsleiter)
CVE	Compliance Verification Engineer (Musterprüfingenieur)
QA	Quality Assurance (Qualitätssicherung)
QM	Quality Manager (Qualitätsmanagementbeauftragter)



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RELATED DOCUMENTS


Table 1: Related Documents

Document Name	Name (Content)	Document Number
MAN_iXCOM-CMD.pdf	Manual iXCOM-CMD User GUI for iNAT and iTracERT-MVT systems	DOC151112010


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ABBREVIATIONS

CAD	Conditionally Automated Driving according to SAE Level 3 (hands off, eyes off - sometimes)
CAN	Controller Area Network – automotive bus for data exchange
DHCP	Dynamic Host Configuration Protocol
ETRS89 / ITRF	European / International Terrestrial Reference System / Frame
FAD	Fully Automated Driving according to SAE Level 5 (hands off, mind off - always)
GNSS	Global Navigation Satellite System (GPS, GLONASS, GALILEO, Beidou etc.)
HAD	Highly Automated Driving according to SAE Level 4 (hands off, eyes off, mind off - sometimes)
INS	Inertial Navigation System (also IMS, inertial Measurement System)
ISE	InfraStructure Element (e.g. traffic light, road signs, guardrails)
iARGUS-CC	Control Center of the iSWACO-ARGUS application
iARGUS-CMD	Software applied on the iARGUS-CC Control Center for Traffic Scenario planning, simulation, execution and visualization.
iARGUS-GTG	iMAR's Global Trajectory Generator (applied on the iARGUS-CC Control Center)
iARGUS-LTG	iMAR's Local Trajectory Generator (applied on the Moveable Object)
iARGUS-MON	Monitoring software to monitor all Moveable Objects on broadcast level
iARGUS-RCS	iMAR's roof mounted communication and sensor system (INS/GNSS and optional stereo camera system iARGUS-MV with cognitive/machine vision)
iARGUS-MV	iMAR's machine vision system for environment perception applications
iARGUS-VCS	iMAR's Vehicle Control System and Interface incl. vehicle controller to follow a desired trajectory
iDMN-MHS/FHS/THS	iMAR's Dynamic Mesh Network with hotspots operated mast-mounted (iDMN-MHS), flying (iDMN-FHS) or/and tripod mounted (iDMN-THS)
iDMN-OHS	iMAR's Dynamic Mesh Network object mounted hotspot, i.e. those communication devices, which will provide the wireless communication on the Moveable Objects (VUT, TSV, SCT) and on the active Infrastructure Elements (traffic lights etc.) and acting simultaneously also as hotspot for the data of other participants.
iNAT	iMAR's INS/GNSS/ODO Navigation and Timing solutions for precise dynamic vehicle motion monitoring (see also iTraceRT-MVT)
iREF-L1L2	iMAR's GNSS Reference Station to provide RTK corrections
iSWACO-ARGUS	iMAR's Swarm Control based observation and control application for proving grounds and public roads
iTraceRT-MVT	iMAR's INS/GNSS/ODO solutions for precise dynamic vehicle motion monitoring (same hardware as iNAT devices, but with additional CAN logging function on 2 nd CAN interface)
iXCOM-CMD	Graphical User Interface (GUI) to operate iNAT and iTraceRT-MVT systems
ISE	Infrastructure Element (active: traffic lights, rain simulator etc.; passive: guardrails, traffic signs etc.)

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MRS	Map Reference System (e.g. ETRS89)
MVT	Multi Vehicle Tracking
NTRIP	Networked Transport of RTCM via Internet Protocol
PGRS	Proving Ground Reference System (e.g. WGS84)
rms	root mean square
RPM	Reference Point Marker (physically marked reference point on the proving ground) as position reference (origin point)
RTK	Real Time Kinematic (GNSS centimeter performance level due to the usage of RTK based corrections, distributed via iREF-L1L2 or via GSM / GPRS)
SCT	Soft Crash Target (Moveable Object)
TGEN	Trajectory Generator
TSV	Traffic Simulation Vehicle (Moveable Object)
TTC	Time-to-Collision
UTM	Universal Transverse Mercator (global, Cartesian based coordinate system)
VUT	Vehicle under Test (Subject Vehicle, also part of the group of Moveable Objects)
WGS84	World Geodetic System 1984

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1 INTRODUCTION

iSWACO-ARGUS is the solution for the verification of the safety relevant features of highly automated and fully automated driving vehicles. It covers all SAE levels, i.e. from level 0 “hands on” up to level 5 “optional wheel”, with a single test infrastructure, operable on the proving ground as well as on public roads.

iSWACO-ARGUS controls and monitors the motion behavior of all vehicles on the proving ground simultaneously and in real-time (Figure 1) and gives the operator the unmatched flexibility to generate and execute repeatable as well as individual tests within real emulated traffic scenarios. It also allows to monitor the motion behavior of a set of vehicles performing maneuvers within a public traffic scenario, in real-time as well as in post-mission, e.g. to test highway chauffeur functionalities. Hence, **iSWACO-ARGUS** stays for “**Swarm Control & Continuous Surveillance**”.

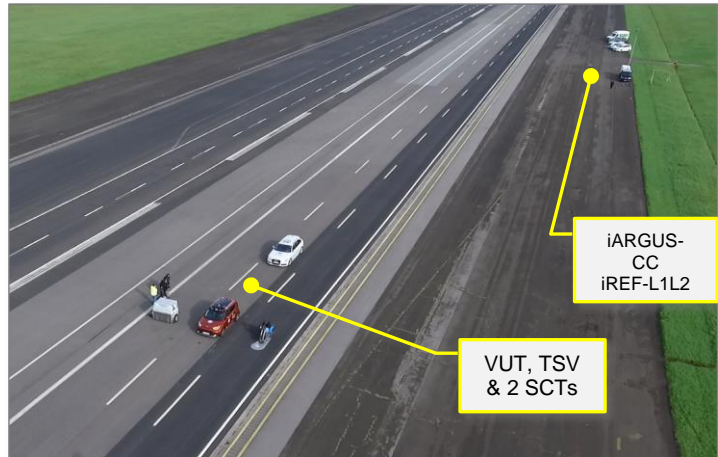


Figure 1: Typical Proving Ground Setup with iSWACO-ARGUS

iSWACO-ARGUS can be installed quickly, simply and safely on nearly arbitrary vehicles, on proving grounds and for public road applications. Thus, it is the testing solution for both, OEMs and testing / certification organizations, to be easily installed on existing or new proving grounds, worldwide.

This document describes the operation of **iSWACO-ARGUS**, which is used to guide several objects regarding to time and location on a proving ground. The task of **iSWACO-ARGUS** is to allow the user to verify the motion behavior of cars and trucks in respect to other moving objects or infrastructure elements under pre-defined Traffic Scenarios.

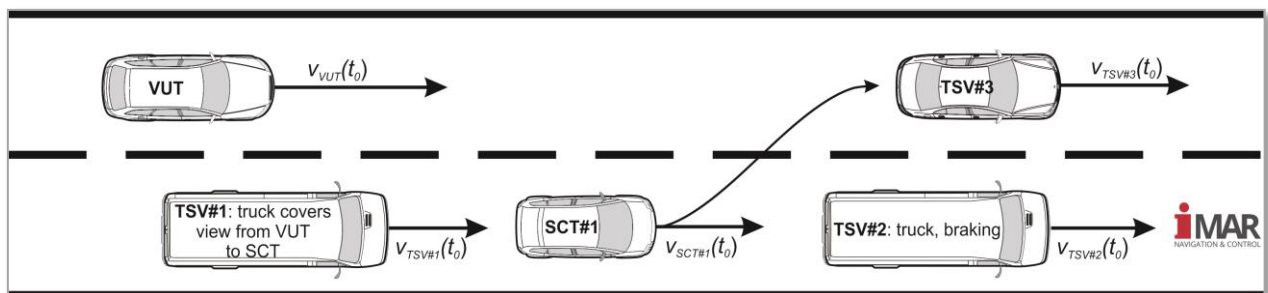



Figure 2: Typical Traffic Scenario

Details about the product **iSWACO-ARGUS** as well as the integrated components (like iNAT and iTraceRT-MVT INS/GNSS localization systems, iARGUS-VCS Vehicle Control System, iREF GNSS reference stations, iDMN Dynamic Mesh Network, iXCOM-CMD Operational Software etc.) can be found also in the datasheets (www.imar-navigation.de) or on request at iMAR’s sales and support engineers.

- [iSWACO-ARGUS Overview](#)
- [iXCOM-CMD Software](#)
- [iNAT-M200: Motion Dynamics and Trajectory Control Reference \(INS/GNSS\) on MEMS basis](#)
- [iNAT-FSSG-1: Motion Dynamics and Trajectory Control Reference \(INS/GNSS\) on FOG basis](#)
- [iNAT-FSLG-01: Motion Dynamics and Trajectory Control Reference \(INS/GNSS\) on high perf. FOG basis](#)
- [iTraceRT-MVT-200 and iTraceRT-MVT-500: Automotive Vehicle Dynamics and Trajectory Control](#)
- [Soft Crash Target \(4a with integrated iNAT-M200\)](#)
- [Video about iSWACO-ARGUS on YouTube](#)


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2 CAPABILITIES & FEATURES OF iSWACO-ARGUS

iSWACO-ARGUS provides the following advantages and features:

- Multiple Vehicle Tracking (MVT) – the measurement solution to track multiple targets (objects) in real-time on the proving ground and on public roads regarding absolute position, orientation and dynamic motion behavior of all targets in respect to any other object.
- iSWACO-ARGUS is used for the validation of entire PAD, HAD and FAD systems, for sensor testing (LiDAR, machine vision, radar etc.), for functionality testing of e.g. ADAS, collision avoidance systems, lane departure warning systems, park assist systems or braking and steering systems and can be applied e.g. for NCAP, IIHS and NHTSA tests.
- Flexible Architecture – easily applicable for existing & new proving grounds regarding infrastructure & topology.
- Cost savings due to the capability to execute individual & fully repeatable test scenarios with minimum personnel effort.
- No steering or driving robots required. Control of Traffic Simulation Vehicle's (TSV) steering / throttle / braking via vehicle's internal actuators or control loops. Therefore, iSWACO-ARGUS saves pretty much setting-up time, compared to competing systems and allows simple set-to-work on arbitrary proving grounds.
- Capability due to modular architecture of iSWACO-ARGUS to integrate also "non-iMAR" components like brake robots or driving or steering robots from ABD, Vehico, Stähle or other manufacturers.
- The iSWACO-ARGUS package includes all you need on the proving ground for Highly Automated Driving (HAD) and Fully Automated Driving (FAD) verification (ongoing expansion of capabilities on demand at iMAR's development and testing department regarding hardware, software, algorithms and ergonomics), i.e.:
 - ✚ Vehicle localization and control for multiple simultaneous moving objects (Traffic Simulation Vehicles TSV, Soft Crash Targets SCT, Vehicle under Test VUT, based on iMAR's INS/GNSS/ODO and cognitive vision technology, also operable in GNSS denied areas of a proving ground (allows also testing the VUT under real GNSS outage conditions).
 - ✚ Collision warning and avoidance system iARGUS-RCS for each vehicle, based on INS/GNSS and machine vision technology.
 - ✚ GNSS RTK correction data acquisition and distribution system iREF-L1L2 to meet position accuracy on centimeter level on the proving ground.
 - ✚ Mobile or stationary Control Center iARGUS-CC with software for trajectory planning, simulation and test execution, test visualization, data storage and data analysis.
 - ✚ Vehicle guidance & control hardware and software (iARGUS-VCS) including vehicle interface.
 - ✚ Mobile iDMN Dynamic Mesh Network for multi vehicle communication with lowest latency, including several options for hotspots (mast mounted iDMN-MHS, flying iDMN-FHS, tripod mounted iDMN-THS), where also each Object itself (VUT, TSV, SCT, active ISEs) is acting with its own iDMN-OHS also as a hotspot.
- The implementation covers the recommendations of the future ISO/WD 22133-1 "Road Vehicles - Test Object Monitoring and Control for Active Safety and Automated/autonomous Vehicle Testing" standard.
- Maintenance & Support Agreement available to participate in the fast evolution of HAD/FAD related testing technologies on the proving ground and on public roads. Ask your iMAR sales engineer for details.
- iSWACO-ARGUS is being developed for one of the largest German testing organizations, intending to provide the homologation (type approval) for automated and autonomous Vehicles under Test (VUT) in the future.

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3 DEFINITIONS AND EXPLANATIONS

This chapter defines the components and expressions used within this manual. It is in accordance to the pre-draft of ISO/WD 22133-1.

3.1 Subject Vehicle (SV)

One or more vehicles to be tested with the system (also called **VUT** – Vehicle under Test)

Note 1 to entry: There may be one subject vehicle (standard setup) or a set of subject vehicles in the specific traffic scenario.

Note 2 to entry: Subject vehicle may be under safety driver control or/and under control center.

3.2 Object

Entity part of a Traffic Scenario under control by control center

Note 1: Two types of entities exist; moveable and stationary objects.

3.2.1 Moveable Object

Object under control by control center which has the capability of moving (mobile / non-stationary target)

Note 1: The SV is typically a Moveable Object.

Note 2: Various levels of control are possible (open-loop control [using no feedback from the real-time activities of other objects or environment], closed-loop control [taking into account activities of other objects in real-time]).

Example: Traffic Support Vehicles (**TSV**), Soft Crash Targets (**SCT**)

3.2.2 Stationary Object

Object, which is not moveable but may be under control by control center

Note 1: The SV may also be a Stationary Object case by case.

Example: active (controlled by control center) and passive Infrastructure Elements (ISE);

Active ISE: e.g. traffic lights, lighting, rain/snow/fog simulator

Passive ISE: e.g. elements of construction area, road signs, guardrails etc.

3.3 iARGUS-CC: Control Center

Centralized or distributed services for object control and safety monitoring including provision of communication services to the objects

3.4 Traffic Scenario

Complete scenario including all objects (moveable as well as stationary objects) and definition of the planned activities over time or/and location.

3.5 Moveable Object's Trajectory

Planned trajectory including object position, heading and object motion dynamics for each individual Moveable Object as part of the Traffic Scenario.

3.6 Safety Limited Speed

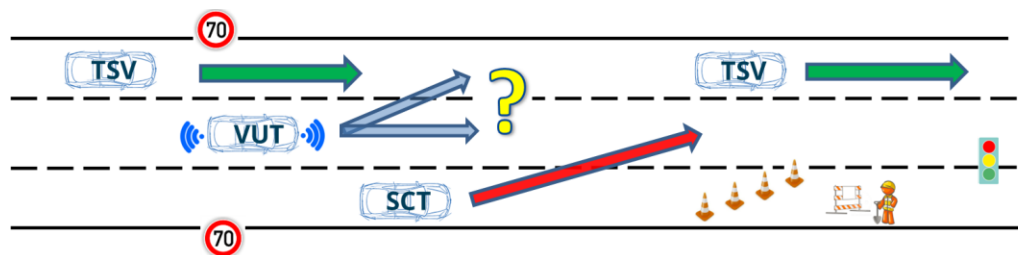
Maximum speed for repositioning moveable objects while not in testing mode (i.e. when outside of the Traffic Scenario)





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4 TRAFFIC SCENARIO ILLUSTRATION

The illustration of a traffic scenario in Figure 3 is used as an example to explain a possible traffic scenario with various objects. The example does not include all possible objects and use cases referred to in the document.

To be able to achieve the following scenario, several different mechanisms can be used to control and monitor all different objects, which will be described later in this document. Some or all objects can be controlled by a server but may be controlled also by a safety driver if allowed by the hardware.



Type of Object	re-positioning and safe return function	longitudinal and lateral guidance during the test (SAE automation level)	collision avoidance during the test
	iARGUS-VCS or Safety Driver	iARGUS-VCS (fully automated driving – SAE level 5)	iARGUS-VCS or Safety Driver
	./.	./.	./.
	Safety Driver or iARGUS-VCS	PAD - Level 2: „partial“, hands off & eyes on CAD – Level 3: “conditional“, hands off & eyes off - sometimes HAD - Level 4: „high“, hands off & eyes off & mind off - sometimes FAD - Level 5: „full“, no human driver required anymore	Safety Driver or iARGUS-VCS
	iARGUS-CC	iARGUS-CC	iARGUS-CC

VUT = Vehicle under Test • TSV = Traffic Simulation Vehicle • SCT = Soft Crash Target • ISE = InfraStructure Element

Figure 3: Traffic Scenario example

5 COORDINATE SYSTEMS AND TIME REFERENCE

5.1 Vehicle Coordinate System (TSV, SCT, VUT)

The vehicle's coordinate system orientation follows ISO 8855. See Figure 4 for explanation. If not otherwise stated, the geometrical center of the object, projected on the ground, is used as the origin of the coordinate system.