SPHERA v.8.0 documentation

This documentation file is intended to provide only additional and updated material, beyond the other SPHERA GitHub repository files and the associated papers on International Journals (Sec.5).

1. Warranties and responsabilities

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It is also mandatory to cite the use of SPHERA in all the related publications, reports and dissemination tools and media (also included press and digital products), by means of the following citation:
“SPHERA v.8.0 is realised by RSE SpA thanks to the funding “Fondo di Ricerca per il Sistema Elettrico” within the frame of a Program Agreement between RSE SpA and the Italian Ministry of Economic Development (Ministero dello Sviluppo Economico).”

4. SPHERA acknowledgments

SPHERA has been entirely financed by the Research Fund for the Italian Electrical System (for “Ricerca di Sistema -RdS-”), at different stages:

- ✓ under the second period of RdS (2003-2005), where CESI SpA was the only beneficiary of the Research Fund for the Italian Electrical System;

- ✓ under the Contract Agreement between CESI Ricerca SpA and the Italian Ministry of Economic Development for the of RdS period 2006-2008, in compliance with the Decree of 8 March 2006;
- ✓ under the Contract Agreement between ERSE and the Ministry of Economic Development-General Directorate for Energy and Mining Resources (for the of RdS period 2009-2011) stipulated on 29 July 2009 in compliance with the Decree of 19 March 2009.
- ✓ under the Contract Agreement between RSE SpA and the Italian Ministry of Economic Development for the of RdS period 2012-2014, in compliance with the Decree of November 9, 2012.

"We acknowledge the CINECA award under the ISCRA initiative, for the availability of High Performance Computing resources and support." In fact, SPHERA validation has also been financed by means of the following instrumental funding HPC projects:

- ✓ HSPHMI14 - High performance computing for Lagrangian numerical models to simulate free surface and multi-phase flows (SPH) and the scalar transport in turbulent flows (MIcromixing); June 2014 – March 2015; Amicarelli A., G. Agate, G. Leuzzi, P. Monti, R. Guandalini, S. Sibilla; HPC Italian National Research Project (ISCRA-C2); competitive call for instrumental funds;
- ✓ HPCEFM15 - High Performance Computing for Environmental Fluid Mechanics 2015 (Italian National HPC Research Project); instrumental funding based on competitive calls (ISCRA-C project at CINECA, Italy); 2015 - in progress; Amicarelli A., A. Balzarini, S. Sibilla, G. Agate, G. Leuzzi, P. Monti, G. Pirovano, G.M. Riva, A. Toppetti, E. Persi, G. Petaccia, L. Ziane, M.C. Khellaf.

5. Description and references

SPHERA v.8.0 (RSE SpA) is free research software (FOSS) based on the SPH ("Smoothed Particle Hydrodynamics") method, which represents a mesh-less Computational Fluid Dynamics technique for free surface and multi-phase flows. So far, SPHERA has been applied to represent: several types of floods (and landslides) with transport of solid bodies and bed-load transport; sloshing tanks;…

The main numerical developments featuring SPHERA (so far) are listed in chronological reverse order:

- ➢ 3D SPH numerical scheme for the transport of solid bodies in free surface flows. Reference: Amicarelli et al. (2015, CAF):

  Amicarelli A., R. Albano, D. Mirauda, G. Agate, A. Sole, R. Guandalini; 2015; A Smoothed Particle Hydrodynamics model for 3D solid body transport in free surface flows; Computers & Fluids, 116:205–228, DOI 10.1016/j.compfluid.2015.04.018
- ➢ 3D SPH numerical scheme for a boundary treatment based on discrete surface and volume elements, and on a 1D Linearized Partial Riemann Solver coupled with a MUSCL (Monotonic Upstream-Centered Scheme for Conservation Laws) spatial reconstruction scheme. Reference: Amicarelli et al. (2013, IJNME):

  Amicarelli A., G. Agate, R. Guandalini; 2013; A 3D Fully Lagrangian Smoothed Particle Hydrodynamics model with both volume and surface discrete elements; International Journal for Numerical Methods in Engineering, 95, 419–450, DOI: 10.1002/nme.4514.
- ➢ SPH numerical scheme for a 2D erosion criterion. Reference: Manenti et al. (2012, JHE):

  Manenti S., S. Sibilla, M. Gallati, G. Agate, R. Guandalini; 2012; SPH Simulation of Sediment Flushing Induced by a Rapid Water Flow; Journal of Hydraulic Engineering ASCE 138(3): 227-311.
- ➢ 3D SPH numerical scheme for a boundary treatment based on volume integrals, which are numerically computed outside of the fluid domain (semi-analytic approach). Reference: Di Monaco et al. (2011, EACFM):

  Di Monaco A., Manenti S., Gallati M., Sibilla S., Agate G., Guandalini R., 2011; SPH modeling of solid boundaries through a semi-analytic approach; Engineering Applications of Computational Fluid Mechanics, 5, 1, 1–15.

Other major numerical developments are available in SPHERA (i.e. 3D erosion criterion also with mixture-fixed bed interactions; bed-load transport), but their validation only refers to a manuscript submitted to an International Journal.

Since its SPHERA v.7.0 branches, SPHERA has being developed under a Git repository (GitHub web site). Its current version contains the folders of Table 5.1.

SPHERA is free software released under the GNU General Public License (Free Software Foundation).

Folder	Description
(main folder)	License file (GNU-GPL license). Documents on SPHERA registration at SIAE.
doc	Present documentation file.
src	SPHERA source code (with makefile)
bin	SPHERA executable files compiled with gfortran/ifort for run/debug executions
input	Input files for validated test cases (Sec.12). A template for the main input file with comments.

Table 5.1. Folders in SPHERA Git repository.

6. Theory

Please refer to SPHERA main references (Sec.5). The release of further documentation is in progress and coming soon.

7. Installation

SPHERA files are distributed on a dedicated Git repository on GitHub (in case of need, please refer to SPHERA contact email address of Sec.5).
SPHERA executable files are released for Linux OS. The only mandatory argument of the executable file (in the command line) is the name of the main input file (with no format extension ".inp").

8. Official SPHERA users

The release of further documentation is in progress and coming soon.

9. SPHERA support and teaching activities

The release of further documentation is in progress and coming soon.

10. SPHERA developers/authors

The release of further documentation is in progress and coming soon.

11. Doxygen guide

The release of further documentation is in progress and coming soon.

12. User guide

SPHERA repository contains a sequence of input files, whose associated test cases are either reported on International Journal papers or represent analogous simplifications. Please refer to SPHERA main references (Sec.5) and to the verbose template for SPHERA main input file with comments on the input parameters (Table 5.1). The release of further documentation is in progress and coming soon.

13. FAQ

So far, no additional information is relevant.

14. Previous versions (not tracked on SPHERA Git repository)

Table 14.1 reports information on SPHERA v.7.0 files and their relationship with SPHERA v.8.0 program units.

Program unit (SPHERA v.7.0)	First author (SPHERA v.7.0)	SPHERA 8.0 folder	SPHERA v.8.0 file	subroutine(s)/ function(f)/ module(m)/ main(p)	Notes
CancelOutgoneParticles_2D	undef.	BC	CancelOutgoneParticles.f90	s	
CancelOutgoneParticles_3D	undef.	BC	CancelOutgoneParticles.f90	s	
FindFrame	undef.	BC	Sphera_Tools.f90	s	
FindLine	undef.	BC	Sphera_Tools.f90	s	
GenerateSourceParticles_2D	Di Monaco	BC	GenerateSourceParticles.f90	s	
GenerateSourceParticles_3D	Di Monaco	BC	GenerateSourceParticles.f90	s	
IsParticleInternal2D	undef.	BC	Sphera_Tools.f90	f	
IsParticleInternal3D	undef.	BC	Sphera_Tools.f90	f	
NormFix	undef.	BC	Sphera_Tools.f90	s	
NumberSectionPoints	undef.	BC	Sphera_Tools.f90	f	
PreSourceParticles_2D	Di Monaco	BC	GenerateSourceParticles.f90	s	
PreSourceParticles_3D	Di Monaco	BC	GenerateSourceParticles.f90	s	
VelLaw	undef.	BC	Sphera_Tools.f90	s	
CalcPre	undef.	BE_Mass	Sphera_Tools.f90	s	with commented subroutine on Mach check
inter_EqCont_2D	undef.	BE_Mass	Inter.f90	s	
inter_EqCont_3D	undef.	BE_Mass	Inter.f90	s	
inter_SmoothPres	Di Monaco	BE_Mass	Inter.f90	s	
PressureSmoothing_2D	Di Monaco	BE_Mass	PressureSmoothing.f90	s	
PressureSmoothing_3D	Di Monaco	BE_Mass	PressureSmoothing.f90	s	
diffumorris	undef.	BE_Momentum	Sphera_Tools.f90	s	
inter_EqMoto	undef.	BE_Momentum	Inter.f90	s	
inter_SmoothVelo_2D	Di Monaco	BE_Momentum	Inter.f90	s	
inter_SmoothVelo_3D	Di Monaco	BE_Momentum	Inter.f90	s	
viscomon	undef.	BE_Momentum	Sphera_Tools.f90	s	
viscomorris	undef.	BE_Momentum	Sphera_Tools.f90	s	
Body_dynamics_output	Amicarelli	Body_Transport	Body_dynamics.f90	s	
body_particles_to_continuity	Amicarelli	Body_Transport	Body_dynamics.f90	s	
body_pressure_mirror	Amicarelli	Body_Transport	Body_dynamics.f90	s	
body_pressure_postpro	Amicarelli	Body_Transport	Body_dynamics.f90	s	
body_to_smoothing_pres	Amicarelli	Body_Transport	Body_dynamics.f90	s	
body_to_smoothing_vel	Amicarelli	Body_Transport	Body_dynamics.f90	s	
Gamma_boun	Amicarelli	Body_Transport	Body_dynamics.f90	f	
Input_Body_Dynamics	Amicarelli	Body_Transport	Body_dynamics.f90	s	
RHS_body_dynamics	Amicarelli	Body_Transport	Body_dynamics.f90	s	
mixture_viscosity	Amicarelli	Constitutive_Equation	Granular_flows.f90	s	
viscapp	Di Monaco	Constitutive_Equation	Sphera_Tools.f90	s	
adjacent_faces_isolated_points	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
BC_wall_elements	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
DBSPH_find_close_faces	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
DBSPH_IC_surface_elements	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
DBSPH_inlet_outlet	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
DBSPH_kinematics	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
Gradients_to_MUSCL	Amicarelli	DB_SPH	BC_wall_elements.f90	s	

Gradients_to_MUSCL_boundary	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
Import_ply_surface_meshes	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
semi_particle_volumes	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
viscomon_wall_elements	Amicarelli	DB_SPH	BC_wall_elements.f90	s	in drafts.f90
viscomorris_wall_elements	Amicarelli	DB_SPH	BC_wall_elements.f90	s	in drafts.f90
wall_elements_pp	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
wavy_inlet	Amicarelli	DB_SPH	BC_wall_elements.f90	s	
compute_k_BetaGamma	Amicarelli	Erosion_Criterion	Granular_flows.f90	s	
fixed_bed_slope_limited	Amicarelli	Erosion_Criterion	Granular_flows.f90	s	
MohrC	Manenti	Erosion_Criterion	Crit_Erosion.f90	s	in drafts.f90
Shields	Manenti	Erosion_Criterion	Crit_Erosion.f90	s	
area_quadrilateral	Amicarelli	Geometry	Granular_flows.f90	s	
area_triangle	Amicarelli	Geometry	Granular_flows.f90	s	
dis_point_plane	Amicarelli	Geometry	Body_dynamics.f90	s	
distance_point_line_2D	Amicarelli	Geometry	Body_dynamics.f90	s	
distance_point_line_3D	Amicarelli	Geometry	Body_dynamics.f90	s	
IsPointInternal	undef.	Geometry	Sphera_Tools.f90	f	
line_plane_intersection	Amicarelli	Geometry	Granular_flows.f90	s	
LocalNormalCoordinates	Di Monaco	Geometry	Sphera_Tools.f90	s	
Matrix_Inversion_2x2	Amicarelli	Geometry	Body_dynamics.f90	s	
Matrix_Inversion_3x3	Amicarelli	Geometry	Body_dynamics.f90	s	
MatrixProduct	undef.	Geometry	Sphera_Tools.f90	s	
MatrixTransposition	undef.	Geometry	Sphera_Tools.f90	s	
point_inout_polygone	Amicarelli	Geometry	Body_dynamics.f90	s	
quadratic_equation	Amicarelli	Geometry	Granular_flows.f90	s	
reference_system_change	Amicarelli	Geometry	Body_dynamics.f90	s	
three_plane_intersection	Amicarelli	Geometry	Body_dynamics.f90	s	
Vector_Product	undef.	Geometry	Sphera_Tools.f90	s	
vector_rotation	Amicarelli	Geometry	Body_dynamics.f90	s	
GeneratePart	undef.	IC	Sphera_Tools.f90	s	
initialization_fixed_granular_particle	Amicarelli	IC	Granular_flows.f90	s	
SetParticleParameters	Amicarelli	IC	Sphera_Tools.f90	s	
SetParticles	undef.	IC	Sphera_Tools.f90	s	
SubCalcPreIdro	Agate	IC	Sphera_Tools.f90	s	
AggDens	undef.	Interface_Dispersion	Sphera_Tools.f90	s	in drafts.f90
inter_CoefDif	undef.	Interface_Dispersion	Inter.f90	s	in drafts.f90
inter_SmoothVF	Manenti	Interface_Dispersion	Inter.f90	s	in drafts.f90
check_files	undef.	Main algorithm	Sphera_Main.f90	s	in sphera.f90
Gest_Dealloc	undef.	Main algorithm	Sphera_Tools.f90	s	
Gest_Trans	undef.	Main algorithm	Sphera_Tools.f90	s	
Loop_Irre_2D	Di Monaco	Main algorithm	Loop_Irre.f90	s	
Loop_Irre_3D	undef.	Main algorithm	Loop_Irre.f90	s	
sphera	undef.	Main algorithm	Sphera_Main.f90	p	in sphera.f90
AdM_User_Type	Di Monaco	Modules	AdM_User_Type.f90	m	New name: Hybrid_allocation_module
ALLOC_Module	undef.	Modules	Alloc_Module.f90	m	New name: Dynamic_allocation_module
BoundIntegralTab_Module	Di Monaco	Modules	BoundIntegralTab_Module.f90	m	New name: SA_SPH_module
diagnostic_module	undef.	Modules	Diagnostic_Module.f90	m	New name: I_O_diagsnostic_module

english_writime2	undef.	modules	Sphera_Tools.f90	m	New name: I_O_ENG_module
files_entities	undef.	Modules	Files_Entities.f90	m	New name: I_O_file_module
GLOBAL_Module	undef.	Modules	Global_Module.f90	m	New name: Static_allocation_module
italiano_writime2	undef.	modules	Sphera_Tools.f90	m	New name: I_O_ITA_module
language_writime2	undef.	modules	Sphera_Tools.f90	m	New name: I_O_language_module
time_usertype	undef.	Modules	Time_UserType.f90	m	New name: Time_module
CalcVarLength	undef.	Neighbouring_Search	Sphera_Tools.f90	s	
CellIndices	undef.	Neighbouring_Search	Sphera_Tools.f90	f	
CellNumber	undef.	Neighbouring_Search	Sphera_Tools.f90	f	
CreaGrid	undef.	Neighbouring_Search	Sphera_Tools.f90	s	
InterFix	undef.	Neighbouring_Search	Inter.f90	s	
OrdGrid1	undef.	Neighbouring_Search	Sphera_Tools.f90	s	
ParticleCellNumber	undef.	Neighbouring_Search	Sphera_Tools.f90	f	
SearchforParticleZone_3D	Di Monaco	Neighbouring_Search	Sphera_Tools.f90	s	
w	Di Monaco	Neighbouring_Search	Boundaries.f90	f	
calc_pelo	undef.	Post-processing	Sphera_Tools.f90	s	
CalcVarp	undef.	Post-processing	Sphera_Tools.f90	s	
CreateSectionPoints	undef.	Post-processing	Sphera_Tools.f90	s	
GetVarPart	undef.	Post-processing	Sphera_Tools.f90	s	
Memo_Ctl	undef.	Post-processing	Sphera_Tools.f90	s	
Memo_Results	undef.	Post-processing	Sphera_Tools.f90	s	
Print_Results	undef.	Post-processing	Sphera_Tools.f90	s	
result_converter	undef.	Post-processing	Sphera_Tools.f90	s	
s_ctime	undef.	Post-processing	Sphera_Tools.f90	s	
s_secon2	undef.	Post-processing	Sphera_Tools.f90	s	
start_and_stop	Agate	Post-processing	Sphera_Tools.f90	s	
sub_Q_sections	Amicarelli	Post-processing	Granular_flows.f90	s	
Update_Zmax_at_grid_vert_columns	Amicarelli	Post-processing	Granular_flows.f90	s	
write_Granular_flows_interfaces	Amicarelli	Post-processing	Granular_flows.f90	s	
write_h_max	Amicarelli	Post-processing	Granular_flows.f90	s	
writime2	undef.	Post-processing	Sphera_Tools.f90	s	
defcolpartzero	undef.	Pre-processing	Sphera_Tools.f90	s	
diagnostic	Agate	Pre-processing	Sphera_Tools.f90	s	
Gest_Input	undef.	Pre-processing	Sphera_Tools.f90	s	
Init_Arrays	undef.	Pre-processing	Sphera_Tools.f90	s	
ModifyFaces	undef.	Pre-processing	Sphera_Tools.f90	s	
ReadBedLoadTransport	Amicarelli	Pre-processing	ReadInputFile.f90	s	
ReadBodyDynamics	Amicarelli	Pre-processing	ReadInputFile.f90	s	
ReadCheck	undef.	Pre-processing	ReadInputFile.f90	f	
ReadDBSPH	Amicarelli	Pre-processing	ReadInputFile.f90	s	
ReadInput	undef.	Pre-processing	ReadInputFile.f90	s	
ReadInputBoundaries	undef.	Pre-processing	ReadInputFile.f90	s	
ReadInputControlLines	undef.	Pre-processing	ReadInputFile.f90	s	
ReadInputControlPoints	undef.	Pre-processing	ReadInputFile.f90	s	
ReadInputControlSections	undef.	Pre-processing	ReadInputFile.f90	s	
ReadInputDomain	undef.	Pre-processing	ReadInputFile.f90	s	
ReadInputDrawOptions	undef.	Pre-processing	ReadInputFile.f90	s	

ReadInputExternalFile	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputFaces	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputGeneralPhysical	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputLines	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputMedium	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputOutputRegulation	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputParticlesData	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputRestart	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputRunParameters	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputTitle	undef.	Pre-processing	ReadInputFile.f90	s
ReadInputVertices	undef.	Pre-processing	ReadInputFile.f90	s
ReadRestartFile	undef.	Pre-processing	ReadInputFile.f90	s
ReadRiga	undef.	Pre-processing	ReadInputFile.f90	s
ReadSectionFlowRate	Amicarelli	Pre-processing	ReadInputFile.f90	s
AddBoundaryContribution_to_CE2D	Di Monaco	SA_SPH	AddBoundaryContribution.f90	s
AddBoundaryContribution_to_CE3D	Di Monaco	SA_SPH	AddBoundaryContribution.f90	s
AddBoundaryContributions_to_ME2D	Di Monaco	SA_SPH	AddBoundaryContribution.f90	s
AddBoundaryContributions_to_ME3D	Di Monaco	SA_SPH	AddBoundaryContribution.f90	s
AddElasticBoundaryReaction_2D	Di Monaco	SA_SPH	AddBoundaryContribution.f90	s
AddElasticBoundaryReaction_3D	Di Monaco	SA_SPH	AddBoundaryContribution.f90	s
BoundaryMassForceMatrix2D	Di Monaco	SA_SPH	Boundaries.f90	s
BoundaryMassForceMatrix3D	Di Monaco	SA_SPH	Boundaries.f90	s
BoundaryPressureGradientMatrix3D	Di Monaco	SA_SPH	Boundaries.f90	s
BoundaryReflectionMatrix2D	Di Monaco	SA_SPH	Boundaries.f90	s
BoundaryVolumeIntegrals2D	Di Monaco	SA_SPH	Boundaries.f90	s
CompleteBoundaries3D	Di Monaco	SA_SPH	Boundaries.f90	s
ComputeBoundaryDataTab	Di Monaco	SA_SPH	Boundaries.f90	s
ComputeBoundaryIntegralTab	Di Monaco	SA_SPH	Boundaries.f90	s
ComputeBoundaryVolumeIntegrals_P0	Di Monaco	SA_SPH	Boundaries.f90	s
ComputeKernelTable	Di Monaco	SA_SPH	Boundaries.f90	s
ComputeSurfaceIntegral_WdS2D	Di Monaco	SA_SPH	Boundaries.f90	s
ComputeVolumeIntegral_WdV2D	Di Monaco	SA_SPH	Boundaries.f90	s
DefineBoundaryFaceGeometry3D	Di Monaco	SA_SPH	Boundaries.f90	s
DefineBoundarySideGeometry2D	Di Monaco	SA_SPH	Boundaries.f90	s
DefineBoundarySideRelativeAngles2D	Di Monaco	SA_SPH	Boundaries.f90	s
DefineLocalSystemVersors	Di Monaco	SA_SPH	Boundaries.f90	s
EvaluateBER_TimeStep	Di Monaco	SA_SPH	Boundaries.f90	s
FindBoundaryConvexEdges3D	Di Monaco	SA_SPH	Boundaries.f90	s
FindBoundaryIntersection2D	Di Monaco	SA_SPH	Boundaries.f90	s
FindCloseBoundaryFaces3D	DI Monaco	SA_SPH	Boundaries.f90	s
FindCloseBoundarySides2D	Di Monaco	SA_SPH	Boundaries.f90	s
GridCellBoundaryFacesIntersections3D	Di Monaco	SA_SPH	Boundaries.f90	s
InterpolateBoundaryIntegrals2D	Di Monaco	SA_SPH	Boundaries.f90	s
InterpolateTable	Di Monaco	SA_SPH	Boundaries.f90	s
IWro2dro	Di Monaco	SA_SPH	Boundaries.f90	f
J2Wro2	Di Monaco	SA_SPH	Boundaries.f90	f
JdWsRn	Di Monaco	SA_SPH	Boundaries.f90	f

SelectCloseBoundarySides2D	Di Monaco	SA_SPH	Boundaries.f90	s	
WIntegr	Di Monaco	SA_SPH	Boundaries.f90	f	
GetToken	undef.	strings	Sphera_Tools.f90	f	
lcase	undef.	strings	Sphera_Tools.f90	f	
ltrim	undef.	strings	Sphera_Tools.f90	f	
Euler	Amicarelli	Time_Integration	time_integration.f90	s	
Heun	Amicarelli	Time_Integration	time_integration.f90	s	
inidt2	undef.	Time_Integration	Sphera_Tools.f90	s	
rundt2	undef.	Time_Integration	Sphera_Tools.f90	s	
stoptime	undef.	Time_Integration	Sphera_Tools.f90	s	
time_integration	Amicarelli	Time_Integration	time_integration.f90	s	
time_integration_body_dynamics	Amicarelli	Time_Integration	time_integration.f90	s	
KeyDecoderCheck	Agate		KeyDecoderCheck.f90	s	Erased permanently
sloshing_tank_control_points	Amicarelli		DB-SPH_hard_coding.f90	s	Erased permanently

Table 14.1. File and Copyright information on SPHERA v.7.0; relationships with SPHERA v.8.0 program units.

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