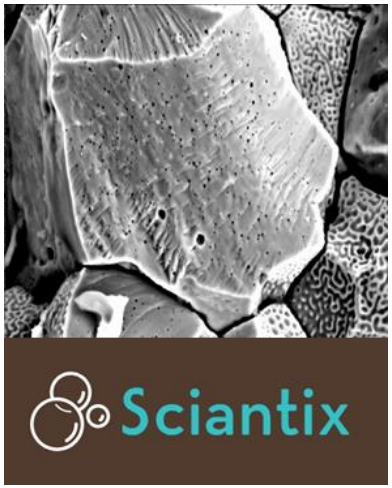
REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

POLITECNICO MILANO 1863



SCIANTIX Virtual Training - October 16, 2020

SCIANTIX: Code structure and input/output

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The SCIANTIX code

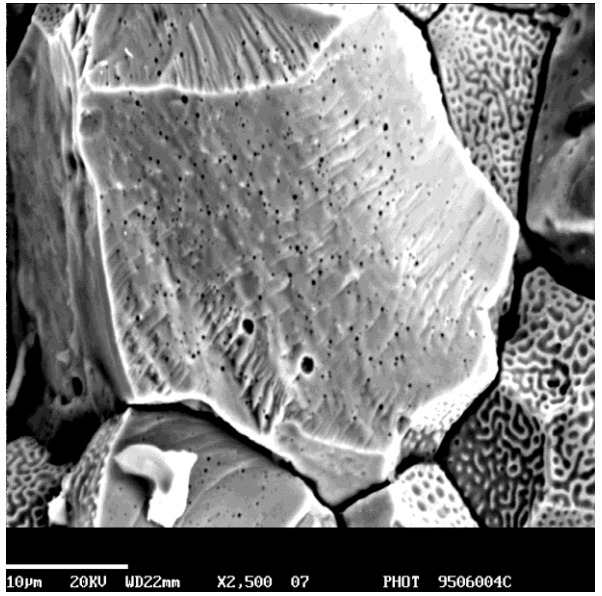
Developed at Politecnico di Milano

It is a **0D stand-alone code, designed to be included as a mechanistic fission gas behaviour module in existing fuel performance codes**

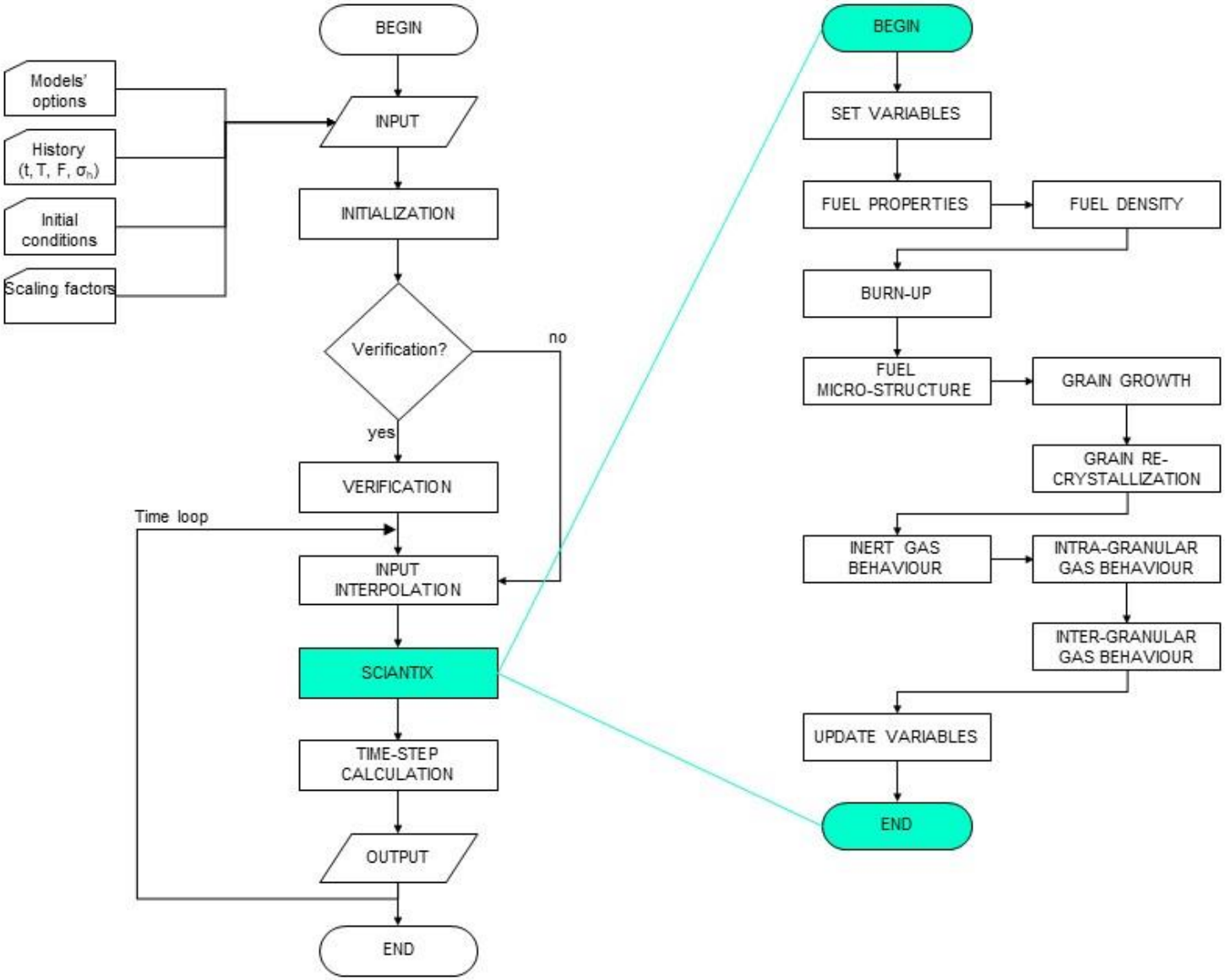
Constitutes the natural environment for the development, verification, and validation of fission gas behaviour models, and for the **simulation of separate-effect test experiments**

It can be **included in existing multiphysics platforms and fuel performance codes as a module** to evaluate fission gas release and gaseous swelling or can be **used as stand-alone**

Available as open-source software (MIT license)

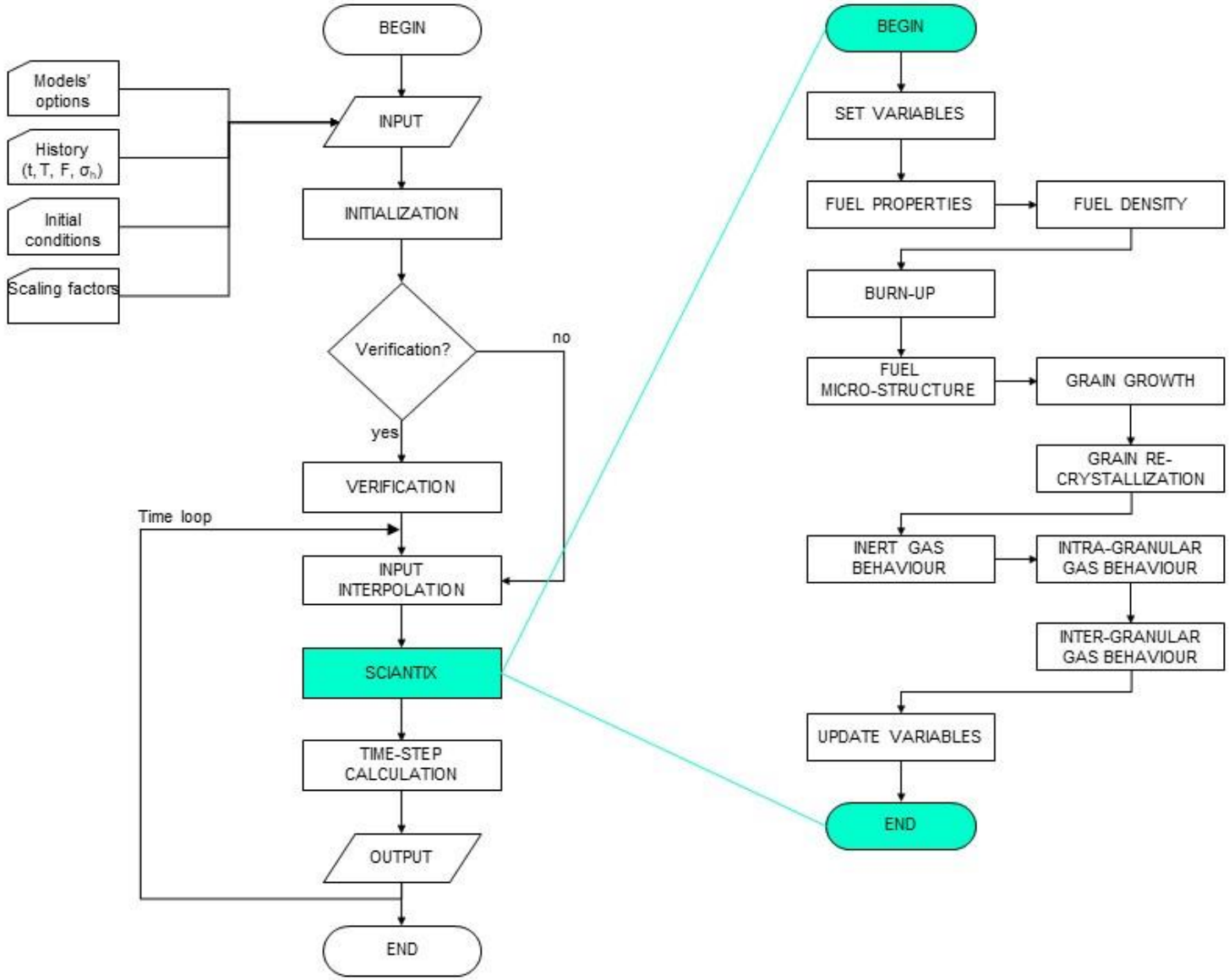


The SCIANTIX code, stand-alone



The SCIANTIX code, designed for coupling !

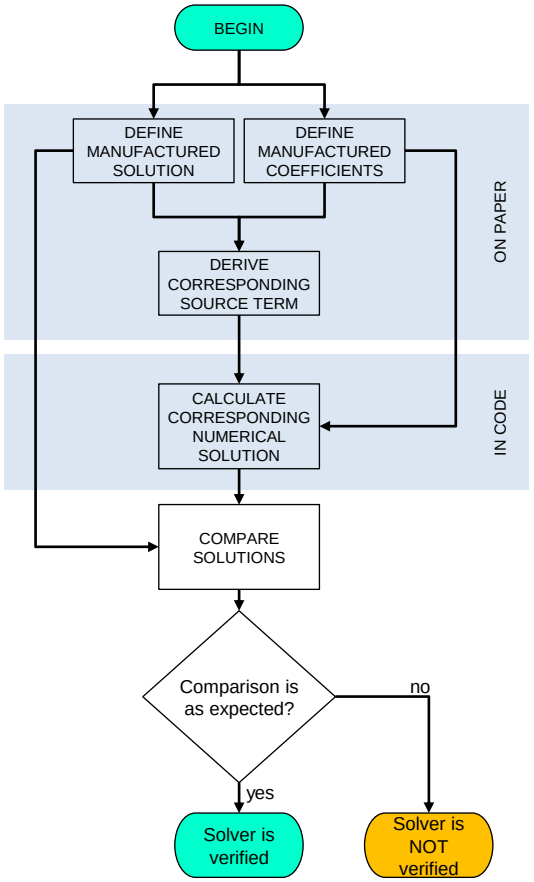
Fuel performance code



The SCIANTIX code, numerical aspects

Numerical solvers (coded) independently from the "physics" allows for once and for all numerical verification

Numerical verification through the Method of Manufactured Solutions



The included models are a combination of PDEs (essentially diffusion of gas along the grain) and ODEs

- Space is treated via a **mesh-free spectral approach**
- Time is treated with **implicit first order** scheme (backward Euler)

Computational times for the simulation of fission gas diffusion//intra-granular behaviour//inter-granular behaviour in the order of **few milliseconds per time-step**

The SCIANTIX code, input files

input_settings.txt

input_initial_conditions.txt

input_history.txt

input_scaling_factors.txt

```
0 #  verification (0= no verification)
1 #  grain growth (1 = ainscough)
1 #  inert gas behavior (1= do IGB)
1 #  gas diff coeff (1= Turnbull et al., 1988)
1 #  intra bbl evo (1=Pizzocri et al., 2018)
1 #  intra bubble_radius (1= Olander&Wongy, 2006)
1 #  re-solution (1=Turnbull 1971)
1 #  trapping (1= Ham 1958)
1 #  nucleation (1= Baker 1971)
1 #  DiffSolver (1= SDA, Pizzocri et al., 2019)
1 #  format_out (1 = output.txt, values separated by tabs)
1 #  gb vac diff coeff (1= Reynolds and Burton, 1979)
1 #  gb behavior (1= do InterGranularGasBehavior - Pastore et
1 #  gb micro-cracking (1 = Barani et al., 2017)
0 #  grain recrystallization (0 = non active)
0 #  fuel/reactor couple for burnup calculations (0=UO2/PWR)
```

Integers allowing to turn on//off different models and to select different options for coefficients

After the "#", there is the place for a comment line

The SCIANTIX code, input files

input_settings.txt

input_initial_conditions.txt

input_history.txt

input_scaling_factors.txt

```
12.3e-6 # initial grain radius (m)
0 # initial Gas produced (at/m3)
0 # initial Gas in grains (dissolved plus ig bubbles) (at/m3)
0 # initial Gas in solution (at/m3)
0 # initial Gas in ig bubbles (at/m3)
0 # initial Gas in gb bubbles (at/m3)
0 # initial Gas released (at/m3)
0 # initial fuel burnup (MWd/kgUO2)
0 # initial effective fuel burnup (MWd/kgUO2)
10970 # initial fuel density (kg/m3)
2 # initial O/M (/)
0 # initial He produced (every manner) (at/m3)
0 # initial He in grains (dissolved plus ig bubbles) (at/m3)
0 # initial He in solution (at/m3)
0 # initial He in ig bubbles (at/m3)
0 # initial He in gb bubbles (at/m3)
0 # initial He released (at/m3)
0 3 0 0 97
# initial U234 U235 U236 U237 U238 (% of heavy atoms) content
0 0 0
# initial Np237 Np238 Np239 (% of heavy atoms) content
0 0 0 0 0 0
# initial Pu238 Pu239 Pu240 Pu241 Pu242 Pu243 (% of heavy atoms) conte
0 0 0 0 0
# initial Am241 Am242g Am242m Am243 Am244 (% of heavy atoms) content
0 0 0 0
# initial Cm242 Cm243 Cm244 Cm245 (% of heavy atoms) content
```

The SCIANTIX code, input files

Fuel performance code

input_settings.txt

input_initial_conditions.txt

input_history.txt

input_scaling_factors.txt

t (h)	T (K)	F (fiss m^{-3} s^{-1})	σ_h (MPa)
0	1157	4.15e18	-0.21
35316.871	1157	4.15e18	-0.21
35604.871	1157	4.15e18	-0.21
35604.8963	2048	1.08e19	-14.8
35605.3963	2048	1.08e19	-14.8
35605.4241	1157	4.15e18	-0.21
35607.0741	1157	4.15e18	-0.21
35607.1241	573	0	0

Piece-wise linear interpolation among the input points

Standard time-stepper divides time-intervals

All input points are always calculated

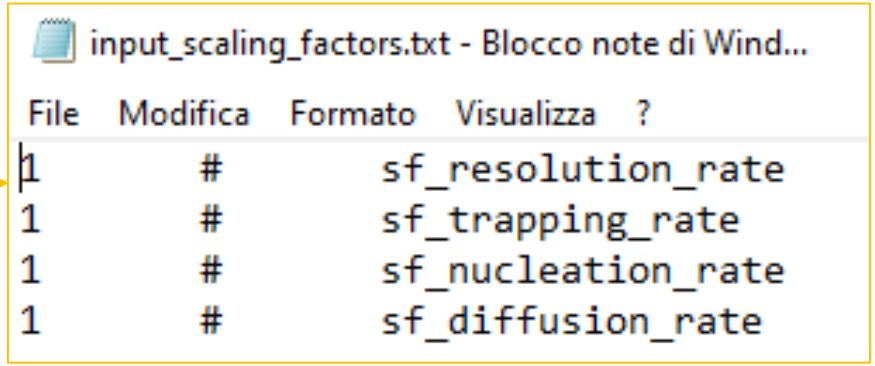
The SCIANTIX code, input files

input_settings.txt

input_initial_conditions.txt

input_history.txt

input_scaling_factors.txt



Optional !

Allows for performing Monte Carlo sensitivity analyses by using external scripts (Matlab)

The SCIANTIX code, output files

Output can be dumped at different time-steps

Ctrl + A
Ctrl + C
Ctrl + V in Excel ☺

Time (h)		Temperature (K)	Fission rate (fiss/m3-s)		Hydrostatic stress (MPa)			
0	1157	4.15e+018	-0.21	1.23e-005	0	0	0	0	0
35.3169	1157	4.15e+018	-0.21	1.22998e-005	1.5829e+023	1.57354e+023	1.5		
70.6337	1157	4.15e+018	-0.21	1.22995e-005	3.1658e+023	3.14044e+023	2.6		
105.951	1157	4.15e+018	-0.21	1.22993e-005	4.74871e+023	4.7015e+023	3.8		
141.267	1157	4.15e+018	-0.21	1.22991e-005	6.33161e+023	6.25677e+023	5.2		
176.584	1157	4.15e+018	-0.21	1.22988e-005	7.91451e+023	7.80717e+023	6.5		
211.901	1157	4.15e+018	-0.21	1.22986e-005	9.49741e+023	9.35338e+023	7.9		
247.218	1157	4.15e+018	-0.21	1.22984e-005	1.10803e+024	1.08959e+024	9.2		
282.535	1157	4.15e+018	-0.21	1.22981e-005	1.26632e+024	1.24353e+024	1.0		
317.852	1157	4.15e+018	-0.21	1.22979e-005	1.42461e+024	1.39717e+024	1.1		
353.169	1157	4.15e+018	-0.21	1.22977e-005	1.5829e+024	1.55056e+024	1.3		
388.486	1157	4.15e+018	-0.21	1.22974e-005	1.74119e+024	1.70373e+024	1.4		
423.802	1157	4.15e+018	-0.21	1.22972e-005	1.89948e+024	1.85668e+024	1.5		
459.119	1157	4.15e+018	-0.21	1.2297e-005	2.05777e+024	2.00945e+024	1.7		
494.436	1157	4.15e+018	-0.21	1.22968e-005	2.21606e+024	2.16204e+024	1.8		
529.753	1157	4.15e+018	-0.21	1.22965e-005	2.37435e+024	2.31448e+024	1.9		
565.07	1157	4.15e+018	-0.21	1.22963e-005	2.53264e+024	2.46677e+024	2.0		
600.387	1157	4.15e+018	-0.21	1.22961e-005	2.69093e+024	2.61892e+024	2.2		
635.704	1157	4.15e+018	-0.21	1.22958e-005	2.84922e+024	2.77094e+024	2.3		
671.021	1157	4.15e+018	-0.21	1.22956e-005	3.00751e+024	2.92284e+024	2.4		
706.337	1157	4.15e+018	-0.21	1.22954e-005	3.1658e+024	3.07463e+024	2.6		
741.654	1157	4.15e+018	-0.21	1.22951e-005	3.32409e+024	3.2263e+024	2.7		
776.971	1157	4.15e+018	-0.21	1.22949e-005	3.48238e+024	3.37786e+024	2.8		
812.288	1157	4.15e+018	-0.21	1.22947e-005	3.64067e+024	3.52932e+024	3.0		
847.605	1157	4.15e+018	-0.21	1.22944e-005	3.79897e+024	3.68068e+024	3.1		
882.922	1157	4.15e+018	-0.21	1.22942e-005	3.95726e+024	3.83194e+024	3.2		
918.239	1157	4.15e+018	-0.21	1.2294e-005	4.11555e+024	3.9831e+024	3.3		
953.556	1157	4.15e+018	-0.21	1.22937e-005	4.27384e+024	4.13417e+024	3.5		
988.872	1157	4.15e+018	-0.21	1.22935e-005	4.43213e+024	4.28515e+024	3.6		

The SCIANTIX code, coupling with FPCs TRANSURANUS & GERMINAL & OFFBEAT

SCIANTIX INPUT
Settings
Initial conditions
(Scaling factors)

Interface binding C++ and F95 code (independent of further SCIANTIX development!) (2 *.C and 2 *.f95) developed for the coupling with TRANSURANUS

SCIANTIX and FPC are compiled together, generating one single executable

- Easier to handle for present users of FPCs
- No need for major modification to FPC input//output
- Strategy is tailored for each FPC

INSPYRE
Investigations Supporting MOX Fuel Licensing in ESNII Prototype Reactors

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& Thank you for your kind attention !