1.4 Summary of Updates from Version 3.1

PFC^{3D} 4.0 contains several improvements. The new features are summarized in the following sections. Please note that, due to these changes, existing data files created for Version 3.1 may not operate correctly in *PFC*^{3D} 4.0. In particular, data files that make use of the **CLUMP** command and the user-defined contact model (UDM) option must be modified. In both cases, the previous functionality is preserved, but the **CLUMP** command syntax has changed and the UDM interface has changed. It should be relatively straightforward to modify existing data files to work properly in Version 4.0. Also, *PFC*^{3D} 4.0 cannot restore "SAV" files produced by earlier versions of the code.

1.4.1 Smooth-Joint Contact Model

The representation of interfaces in *PFC*^{3D} models consisting of assemblies of bonded spheres is problematic because of the inherent roughness (bumpiness) of the interface surfaces. Small particles may be used to represent a band of low-strength material, with several particles across the band, but this is not feasible when the model requires a large number of interfaces. The smooth-joint contact model simulates the behavior of an interface regardless of the local particle contact orientations along the interface. The behavior of a frictional or bonded joint can be modeled by assigning smooth-joint models to all contacts between particles that lie upon opposite sides of the joint. Particle pairs joined by a smooth-joint contact may overlap and "slide" past each other instead of being forced to move around one another. The smooth-joint methodology effectively eliminates the bumpiness, and allows specification of macroscopic joint properties. The smooth-joint contact model is described in Section 2.2.2 in **Theory and Background**, and applications of the model to study rock behavior at both large and small scales, ranging from granite grains to an entire open-pit slope, are discussed in Mas Ivars et al. (2008).

1.4.2 Enhanced Clump Logic

The clump logic has been enhanced to make it easier to create models with clumps, and to assign properties and boundary conditions to such models. The following enhancements have been made:

1. The clump interface has been modified such that all commands that apply to balls now have counterparts for clumps, and similar *FISH* access is provided for balls and clumps.

2. Generation of clumped materials has been made easier via the **CLUMP replace** and **CLUMP scale** commands. Starting with an assembly of spheres, specified fractions of these spheres can be replaced with arbitrarily oriented clumps, each of which has the same volume as its replaced sphere. General clump shapes can be specified by defining a set of clump templates that define relative particle locations and sizes within each clump. Packing density may be controlled by performing self-similar scaling of clump sizes with the **CLUMP scale** command.

3. The measurement logic now computes porosity, stress and coordination number for a material consisting of spherical particles and clumps.

1.4.3 Enhanced PFC Fishtank

The *PFC Fishtank* (see Section 3 in the ***FISH* volume**) provides a set of well-defined material vessels within which a material comprised of grains and cement can be formed at a specified pressure using the material-genesis procedure of Potyondy and Cundall (2004). The grains are rigid, and the cement is contact and/or parallel bonds. Granular material is produced by not adding cement during the final stage of the procedure. The material is isotropic, and the grains are well-connected. The enhancements to the *PFC Fishtank* include the ability to define generalized grain shapes (using clump templates), refine grain size in specified refinement regions, and specify multiple material regions.

1.4.4 64-Bit Version

The standard *PFC3D* 4.0 package includes a 64-bit executable, in addition to the 32-bit executable, that is operable on a 64-bit processor computer running the Windows XP X64 or Windows Vista 64-bit operating system. The 64-bit executable will allow a virtually unlimited model size (17 billion GB of addressable memory). The 64-bit executable is functionally equivalent to the 32-bit executable. Note that the 64-bit executable differs from the 32-bit executable only in the fact that additional RAM is available; the 64-bit executable will not run faster than the 32-bit executable.

1.4.5 Compiled HTML Help

The entire **Command Reference**, **FISH in PFC3D** and **Verification Problems and Example Applications** volumes are included as an HTML help file that can be accessed from within the *PFC3D* program. This on-screen reference provides rapid, searchable access to the information contained within these volumes.

1.4.6 Advanced Fluid-Particle Simulation Capability

PFC3D 4.0 provides a new fluid analysis capability, in addition to the basic fluid-analysis option described in **Optional Features**. The new capability is provided as an add-on to *PFC3D* 4.0 that couples the *PFC3D* program with the Coupled Computational Fluid Dynamics (CCFD) program to simulate fluid flow and fluid-particle interaction within arbitrarily shaped volumes. CCFD is a product of ITOCHU Techno-Solutions Corporation (CTC) in Tokyo, Japan. Itasca and CTC have partnered to develop the coupled operation of *PFC3D* and CCFD for fluid analysis. The new add-on is not described in this manual; contact Itasca for information.