

JUG Augsburg, 19.01.2021

Ich packe meinen Testtoolkoffer und nehme
mit...

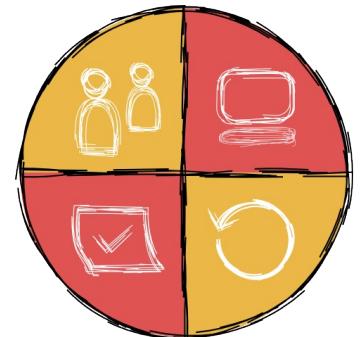
Testwerkzeuge für den Entwickleralltag

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Zu meiner Person

- Sandra Parsick
- Freiberuflicher Softwareentwickler und Consultant im Java-Umfeld
- Schwerpunkte:
 - Java Enterprise Anwendungen
 - Agile Methoden
 - Software Craftmanship
 - Automatisierung von Entwicklungsprozessen
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Das kann man
lokal nicht testen.

Das ist zu
aufwendig zu testen.

Das kann man
nicht testen.



CHALLENGE ACCEPTED

Agenda

Integrierte Tests

equals, hashCode,
toString

Testcode-
Duplikierung

Testdaten

Concurrency

Schlecht lesbare
Assertions

Tests, die nur unter bestimmten
Bedingungen laufen

Problem: Diese Tests können nur unter bestimmten Bedingungen laufen.

JUnit 5 – Conditional Test Execution

```
3 // Operating System Conditions
4
5 @Test
6 @EnabledOnOs(OS.LINUX)
7 void testForLinux(){
8     assertTrue(true);
9 }
10
11 @Test
12 @EnabledOnOs(OS.WINDOWS)
13 void testForWindows(){
14     assertTrue(true);
15 }
16
17 @Test
18 @EnabledOnOs({OS.LINUX, OS.WINDOWS})
19 void testForLinuxAndWindows(){
20     assertTrue(true);
21 }
22
23 @Test
24 @DisabledOnOs(OS.LINUX)
25 void testNotForLinux(){
26     assertTrue(true);
27 }
```

```
29 // Java Runtime Environment Conditions
30
31 @Test
32 @EnabledOnJre(JRE.JAVA_8)
33 void onlyOnJava8() {
34     assertTrue(true);
35 }
36
37 @Test
38 @EnabledOnJre({ JRE.JAVA_9, JRE.JAVA_10 })
39 void onJava9Or10() {
40     assertTrue(true);
41 }
42
43 @Test
44 @DisabledOnJre(JRE.JAVA_8)
45 void notOnJava8() {
46     assertTrue(true);
47 }
```

JUnit 5 – Conditional Test Execution

```
50     // System Property Conditions
51
52     @Test
53     @EnabledIfSystemProperty(named = "os.arch", matches = ".*64.*")
54     void onlyOn64BitArchitectures() {
55         assertTrue(true);
56
57     }
58
59     @BeforeEach
60     void setup(){
61         System.setProperty("ci-server", "true");
62     }
63
64     @Test
65     @DisabledIfSystemProperty(named = "ci-server", matches = "true")
66     @EnabledIfSystemProperty(named = "ci-server", matches = "true")
67     void notOnCiServer() {
68         assertTrue(true);
69     }
```

JUnit 5 – Conditional Test Execution

```
71     // Environment Variable Conditions
72     // variable can be set in idea run configuration
73     // ENV1=staging-server
74     // ENV2=local.development
75
76     @Test
77     @EnabledIfEnvironmentVariable(named = "ENV1", matches = "staging-server")
78     void onlyOnStagingServer() {
79         assertTrue(true);
80     }
81
82     @Test
83     @DisabledIfEnvironmentVariable(named = "ENV2", matches = ".*development.*")
84     void notOnDeveloperWorkstation() {
85         assertTrue(true);
86     }
87
```

Problem: Testcode Duplizierung

```
public class Position {  
  
    private int xCoordinate;  
    private int yCoordinate;  
  
    public Position(int xCoordinate, int yCoordinate) {  
        this.xCoordinate = xCoordinate;  
        this.yCoordinate = yCoordinate;  
    }  
  
    public Position moveBackward(Direction facingDirection) {  
        int newX = xCoordinate;  
        int newY = yCoordinate;  
        switch (facingDirection) {  
            case NORTH:  
                newY--;  
                break;  
            case SOUTH:  
                newY++;  
                break;  
            case WEST:  
                newX++;  
                break;  
            case EAST:  
                newX--;  
                break;  
        }  
        return new Position (newX, newY);  
    }  
  
    public Position moveForward(Direction facingDirection) {  
        int newX = xCoordinate;  
        int newY = yCoordinate;  
  
        switch (facingDirection) {  
            case NORTH:  
                newY++;  
                break;  
            case SOUTH:  
                newY--;  
                break;  
            case WEST:  
                newX--;  
                break;  
            case EAST:  
                newX++;  
                break;  
        }  
  
        return new Position(newX, newY);  
    }  
}
```

Naiver Ansatz

```
7  class PositionNaiveTest {  
8  
9      @Test  
10     void moveBackward_toNorth() {  
11         Position positionUnderTest = new Position(10, 10);  
12  
13         Position newPosition = positionUnderTest.moveBackward(Direction.NORTH);  
14  
15         assertThat(newPosition).isEqualTo(new Position(10, 9));  
16     }  
17  
18     @Test  
19     void moveBackward_toEast() {  
20         Position positionUnderTest = new Position(10, 10);  
21  
22         Position newPosition = positionUnderTest.moveBackward(Direction.EAST);  
23  
24         assertThat(newPosition).isEqualTo(new Position(9, 10));  
25     }  
26 }
```

```
~~~  
27     @Test  
28     void moveBackward_toSouth() {  
29         Position positionUnderTest = new Position(10, 10);  
30  
31         Position newPosition = positionUnderTest.moveBackward(Direction.SOUTH);  
32  
33         assertThat(newPosition).isEqualTo(new Position(10, 11));  
34     }  
35  
36     @Test  
37     void moveBackward_toWest() {  
38         Position positionUnderTest = new Position(10, 10);  
39  
40         Position newPosition = positionUnderTest.moveBackward(Direction.WEST);  
41  
42         assertThat(newPosition).isEqualTo(new Position(11, 10));  
43     }  
44 }  
45
```

Parametrisierte Tests mit JUnit 4

```
1 @RunWith(Parameterized.class)
2 public class PositionMoveBackwardJUnit4Test {
3
4     private final Direction direction;
5     private final Position expectedPosition;
6
7     public PositionMoveBackwardJUnit4Test(Direction direction, Position expectedPosition) {
8         this.direction = direction;
9         this.expectedPosition = expectedPosition;
10    }
11
12    @Parameterized.Parameters
13    public static Collection moveBackwardParameter() {
14        return Arrays.asList(new Object[][]{
15            {Direction.NORTH, new Position(10, 9)},
16            {Direction.EAST, new Position(9, 10)},
17            {Direction.SOUTH, new Position(10, 11)},
18            {Direction.WEST, new Position(11, 10)}
19        });
20    }
21
22    @Test
23    public void moveBackward() {
24        Position positionUnderTest = new Position(10, 10);
25        Position newPosition = positionUnderTest.moveBackward(direction);
26        assertThat(newPosition).isEqualTo(expectedPosition);
27    }
28}
```

```
1 @RunWith(Parameterized.class)
2 public class PositionMoveForwardJUnit4Test {
3
4     private final Direction direction;
5     private final Position expectedPosition;
6
7     public PositionMoveForwardJUnit4Test(Direction direction, Position expectedPosition) {
8         this.direction = direction;
9         this.expectedPosition = expectedPosition;
10    }
11
12    @Parameterized.Parameters
13    public static Collection moveBackwardParameter() {
14        return Arrays.asList(new Object[][]{
15            {Direction.NORTH, new Position(10, 11)},
16            {Direction.EAST, new Position(11, 10)},
17            {Direction.SOUTH, new Position(10, 9)},
18            {Direction.WEST, new Position(9, 10)}
19        });
20    }
21
22    @Test
23    public void moveForward() {
24        Position positionUnderTest = new Position(10, 10);
25
26        Position newPosition = positionUnderTest.moveForward(direction);
27
28        assertThat(newPosition).isEqualTo(expectedPosition);
29    }
30}
```

Parametrisierte Test mit JUnit5

```
1 class PositionJUnit5Test {
2
3     @ParameterizedTest
4     @MethodSource("createMoveBackwardParameter")
5     void moveBackward(Direction direction, Position expectedPosition) {
6         Position positionUnderTest = new Position(10, 10);
7         Position newPosition = positionUnderTest.moveBackward(direction);
8         assertThat(newPosition).isEqualTo(expectedPosition);
9     }
10
11    private static Stream<Arguments> createMoveBackwardParameter() {
12        return Stream.of(
13            Arguments.of(Direction.NORTH, new Position(10, 9)),
14            Arguments.of(Direction.EAST, new Position(9, 10)),
15            Arguments.of(Direction.SOUTH, new Position(10, 11)),
16            Arguments.of(Direction.WEST, new Position(11, 10))
17        );
18    }
19
20    @ParameterizedTest
21    @MethodSource("createMoveForwardParameter")
22    void moveForward(Direction direction, Position expectedPosition) {
23        Position positionUnderTest = new Position(10, 10);
24        Position newPosition = positionUnderTest.moveForward(direction);
25        assertThat(newPosition).isEqualTo(expectedPosition);
26    }
27
28    private static Stream<Arguments> createMoveForwardParameter() {
29        return Stream.of(
30            Arguments.of(Direction.NORTH, new Position(10, 11)),
31            Arguments.of(Direction.EAST, new Position(11, 10)),
32            Arguments.of(Direction.SOUTH, new Position(10, 9)),
33            Arguments.of(Direction.WEST, new Position(9, 10))
34        );
35    }
36}
```

Weitere Möglichkeiten in JUnit5

```
@ParameterizedTest
@ValueSource(strings = {"a", "b", "c"})
void singleLetter(String candidate) {
    assertTrue(isSingleLetter(candidate));
}

private boolean isSingleLetter(String candidate) {
    return candidate.length() == 1;
}

// type for value sources:
// short
// byte
// int
// long
// float
// double
// char
// java.lang.String
// java.lang.Class

@ParameterizedTest
@EnumSource(TimeUnit.class)
void timeUnit(TimeUnit timeUnit) {
    assertThat(timeUnit).isNotNull();
}
```

```
@ParameterizedTest
@CsvSource({ "foo, 1", "bar, 2",
            "'baz, qux', 3" })
// @CsvFileSource(resources = "/test-data.csv", numLinesToSkip = 1)
void testWithCsvSource(String first, int second) {
    assertNotNull(first);
    assertEquals(0, second);
}
```

```
@ParameterizedTest
@ArgumentsSource(MyArgumentsProvider.class)
void testWithArgumentsSource(String argument) {
    assertNotNull(argument);
}
```

```
public class MyArgumentsProvider implements ArgumentsProvider {
    @Override
    public Stream<? extends Arguments> provideArguments(
        ExtensionContext extensionContext) {
        return Stream.of("foo", "bar").map(Arguments::of);
    }
}
```

Parametrisierte Test mit Spock

```
1 class PositionSpockTest extends Specification {
2
3     def "move backward" (Direction direction, Position expectedPosition){
4         Position positionUnderTest = new Position(10, 10)
5         Position newPosition = positionUnderTest.moveBackward(direction)
6
7         expect:
8             assert newPosition == expectedPosition
9
10        where:
11            direction | expectedPosition
12            Direction.NORTH | new Position(10, 9)
13            Direction.EAST | new Position(9, 10)
14            Direction.SOUTH | new Position(10, 11)
15            Direction.WEST | new Position(11, 10)
16    }
17
18    def "move forward" (Direction direction, Position expectedPosition){
19        Position positionUnderTest = new Position(10, 10)
20        Position newPosition = positionUnderTest.moveForward(direction)
21
22        expect:
23            assert newPosition == expectedPosition
24
25        where:
26            direction | expectedPosition
27            Direction.NORTH | new Position(10, 11)
28            Direction.EAST | new Position(11, 10)
29            Direction.SOUTH | new Position(10, 9)
30            Direction.WEST | new Position(9, 10)
31    }
32}
```

Problem: Testdaten

<https://www.generatedata.com>

Name für Datensatz eingeben...

SPEICHERN



LÄNDERSPEZIFISCHE DATEN

Alle Länder

DATENSATZ

Bestell	Spaltenstitel	Datentyp	Beispiele	Optionen	Hilfe	Entf
1	datum	Datum	Mon, Jan 1st, 2012	Von: 10/12/2018 <input type="button" value="..."/> To: 10/12/2020 <input type="button" value="..."/> Format-Code: D, jS, Y	<input type="button" value="?"/>	<input type="checkbox"/>
2	name	Namen, regional	John (männlich Name)	MaleName	<input type="button" value="?"/>	<input type="checkbox"/>
3	str	Straße	Keine Beispiele zur Verfügung.	Keine Optionen verfügbar.	<input type="button" value="?"/>	<input type="checkbox"/>
4	text	Beliebige Anzahl von Wörtern	Keine Beispiele zur Verfügung.	<input type="checkbox"/> Beginnen Sie mit "Lorem ipsum..." Erzeugen # 1 auf # 10 Text	<input type="button" value="?"/>	<input type="checkbox"/>

Bestell Spaltenstitel Datentyp Beispiele Optionen Hilfe Entf

Hinzufügen 1 Zeile(n)

<https://www.generatedata.com>

EXPORT-TYPEN

[CSV](#) [Excel](#) [HTML](#) [JSON](#) [LDIF](#) [Programmiersprache](#) [SQL](#) [XML](#)[- Ausblenden von Daten Format-Optionen](#) Isolieren Sie Leerzeichen aus generierten ErgebnisseDatenstruktur-Format Komplex Einfach

Erzeugen

100

Zeilen

 Hier generieren Neues Fenster / Tab Herunterladen Zip?**Erzeugen**

Daten-Typen auswählen

Human-Daten

Namen

Namen, regional

Telefon / Fax

Telefon / Fax, Regional

E-mail

Datum

Firma

SIRET

Chilean RUT number

Persönliche Nummer

Organisation Anzahl

Geo

Straße

City

Postleitzahl / PLZ

Staat / Provinz / Kreis

Land

Breite / Länge

PIN

CW

Track 1

Track 2

Text

Feste Anzahl der Worte

Beliebige Anzahl von Wörtern

Numerisch

Alphanumerisch

Auto-Inkrement

Number Range

GUID

Currency

Mathe

Standardabweichung

Andere

Konstante

Zusammengesetzt

Tree (übergeordnete Zeile ID)

Benutzerdefinierte Liste

Erstellt 100 100 Ergebnisse

abbrechen



```
1 [
2   {
3     "datum": "Wed, 1st, 2020",
4     "name": "Zachary",
5     "str": "Ap #213-6985 Molestie Straße",
6     "text": "nec mauris blandit mattis. Cras eget"
7   },
8   {
9     "datum": "Fri, 10th, 2019",
10    "name": "Macaulay",
11    "str": "Ap #891-1080 Curabitur Ave",
12    "text": "hendrerit neque. In ornare sagittis felis. Donec tempor, est ac"
13  },
14  {
15    "datum": "Sun, 24th, 2019",
16    "name": "Jonas",
17    "str": "Ap #942-7252 Quam Avenue",
18    "text": "Nam tempor diam dictum sapien. Aenean massa. Integer vitae nibh."
19  },
20  {
21    "datum": "Thu, 4th, 2019",
22    "name": "Adrian",
23    "str": "6794 Egestas, Rd.",
24    "text": "turpis. Aliquam adipiscing lobortis risus."
25  },
26  {
27    "datum": "Mon, 3rd, 2018",
28    "name": "Lev",
29    "str": "Ap #105-239 Arcu Straße",
30    "text": "Sed id risus"
31  },
```



Regenerieren

A A A

Und wenn es doch lieber Code sein soll?

Testdaten mit JavaFaker

```
@Test  
void simpleFaker() {  
    Faker dataFaker = new Faker();  
    Person person = new Person();  
    person.setFirstName(dataFaker.name().firstName());  
    person.setLastName(dataFaker.name().lastName());  
    person.setJobTitle(dataFaker.job().title());  
  
    // more test code  
}
```

- Built-In Faker (Auszug)
 - Business
 - Commerce
 - Name
 - Lorem
- Local Support (Auszug)
 - de (in vielen Varianten)
 - en (in vielen Varianten)

ObjectMother Pattern

```
class PersonTestData { // ObjectMother pattern
    static Person newPersonWithoutJobTitle() {
        Faker dataFaker = new Faker();
        Person person = new Person();
        person.setFirstName(dataFaker.name().firstName());
        person.setLastName(dataFaker.name().lastName());
        return person;
    }

    static Person newPerson() {
        Faker dataFaker = new Faker();
        Person person = new Person();
        person.setFirstName(dataFaker.name().firstName());
        person.setLastName(dataFaker.name().lastName());
        person.setJobTitle(dataFaker.job().title());
        return person;
    }
}
```

```
@Test
void objectMother(){
    Person personWithoutJobTitle =
        PersonTestData.newPersonWithoutJobTitle();
    Person fullPerson =
        PersonTestData.newPerson();

    //more test code
}
```

TestDataBuilder Pattern

```
class PersonTestDataBuilder { // test data builder pattern
    private String firstName;
    private String lastName;
    private String jobTitle;

    PersonTestDataBuilder withFirstName(String firstName){
        this.firstName = firstName;
        return this;
    }

    PersonTestDataBuilder withLastName(String lastName){
        this.lastName = lastName;
        return this;
    }

    PersonTestDataBuilder withJobTitle (String jobTitle){
        this.jobTitle = jobTitle;
        return this;
    }

    Person build() {
        Person person = new Person();
        person.setFirstName(firstName);
        person.setLastName(lastName);
        person.setJobTitle(jobTitle);
        return person;
    }
}
```

```
@Test
void testDataBuilder(){
    Faker dataFaker = new Faker();
    PersonTestDataBuilder personBuilder = new PersonTestDataBuilder();
    personBuilder.withFirstName(dataFaker.name().firstName())
        .withLastName(dataFaker.name().lastName())
        .withJobTitle(dataFaker.job().title());
    Person person = personBuilder.build();
}
```

Problem: Schlecht lesbare Assertion

Built-In Assertion in JUnit

```
@Test  
void builtInAssertion() {  
    Hero hero = new Hero("Batman", "Bruce Wayne");  
  
    assertEquals(hero.getName(), "Batman");  
    assertEquals(hero.getRealName(), "Bruce Wayne");  
}
```

AssertJ – Fluent Assertion API

```
@Test
void hasField(){
    assertThat(new Hero ("Superman", "Clark Kent"))
        .hasFieldOrPropertyWithValue("realName", "Clark Kent")
        .hasFieldOrPropertyWithValue("name", "Superman");
}
```

```
@Test
void basic() {
    assertThat("The Lord of the Rings").isNotNull()
        .startsWith("The")
        .contains("Lord")
        .endsWith("Rings");
}
```

AssertJ – List Assertion

```
@Test
void basic(){
    List<String> heros = List.of("Batman", "Superman");

    assertThat(heros)
        .hasSize(2)
        .contains("Batman")
        .containsExactly("Batman", "Superman")
        .containsAnyOf("Batman", "Superman", "Wonder woman");

    // containsNull
    // negotiation
}

@Test
void extractionSample(){
    List<Hero> heros = List.of(new Hero("Batman", "Bruce Wayne"), new Hero("Superman", "Clark Kent"));

    assertThat(heros)
        .extracting("realName")
        .contains("Bruce Wayne", "Clark Kent");
}
```

AssertJ – Exception Assertion

```
@Test
void bddStyle(){
    // GIVEN
    String[] names = { "Pier ", "Pol", "Jak" };
    // WHEN
    Throwable thrown = catchThrowable(() -> System.out.println(names[9]));
    // THEN
    assertThat(thrown)
        .isInstanceOf(ArrayIndexOutOfBoundsException.class)
        .hasMessageContaining("9");
}

@Test
void assertThatThrownByExample(){
    assertThatThrownBy(() -> { throw new Exception("boom!"); })
        .isInstanceOf(Exception.class)
        .hasMessageContaining("boom")
        .hasMessage("boom!");
}
```

AssertJ – Exception Assertion

```
@Test
void assertThatExceptionOfTypeExample(){
    assertThatExceptionOfType(IOException.class)
        .isThrownBy(() -> { throw new IOException("boom!"); })
        .withMessage("%s!", "boom")
        .withMessageContaining("boom")
        .withNoCause();

    //This later syntax has been enriched for common exceptions :
    //    assertThatNullPointerException
    //    assertThatIllegalArgumentException
    //    assertThatIllegalStateException
    //    assertThatIOException
}

@Test
void assertThatNoExceptionIsThrown(){
    assertThatCode(() -> {
        // code that should NOT throw an exception
    }).doesNotThrowAnyException();
}
```

AssertJ - Assumption

```
@Test
void assume(){
    assumeThat("Bonn").isEqualTo("Bonn");
}

@Test
void assumeMoreComplex(){
    assumeThat(new File("/starwars-testdata/star-wars-logo.png"))
        .isFile()
        .exists();
    assumeThat(List.of("Hello", "World"))
        .hasSize(2)
        .contains("Hello");
}
```

Speziell für DB-Tests: AssertJ-DB

```
@Test
void savePerson() {
    Person person = new Person();
    person.setFirstName("Matt");
    person.setLastName("Clark");
    person.setJobTitle("actor");

    repositoryUnderTest.save(person);

    var personTable = new Table(dataSource, "person");
    assertThat(personTable)
        .column("first_name").containsValues("Matt")
        .column("last_name").containsValues("Clark")
        .column("job_title").containsValues("actor");
}
```



Gibt es speziell
für Neo4j

JUnit 5 – Grouped Assertion

```
@Test
void standardAssertions() {
    assertEquals(2, 2);
    assertEquals(4, 4, "The optional assertion message is now the last parameter.");
    assertTrue('a' < 'b', () -> "Assertion messages can be lazily evaluated -- "
               + "to avoid constructing complex messages unnecessarily.");
}

@Test
void groupedAssertions() {
    // In a grouped assertion all assertions are executed, and any
    // failures will be reported together.
    assertAll("person",
              () -> assertEquals("John", "John"),
              () -> assertEquals("Doe", "Doe"),
              () -> assertThat(Lists.list("foo")).isNotEmpty());
}
```

Exkurs: Migration auf JUnit 5

```
<properties>
    <junit.jupiter.version>5.4.2</junit.jupiter.version>
</properties>

<dependencies>
    <dependency>
        <groupId>org.junit.jupiter</groupId>
        <artifactId>junit-jupiter-api</artifactId>
        <scope>test</scope>
    </dependency>
    <dependency>
        <groupId>org.junit.jupiter</groupId>
        <artifactId>junit-jupiter-engine</artifactId>
        <scope>test</scope>
    </dependency>
    <dependency>
        <groupId>org.junit.vintage</groupId>
        <artifactId>junit-vintage-engine</artifactId>
        <scope>test</scope>
    </dependency>
</dependencies>
```

```
<dependencyManagement>
    <dependencies>
        <dependency>
            <groupId>org.junit</groupId>
            <artifactId>junit-bom</artifactId>
            <version>${junit.jupiter.version}</version>
            <scope>import</scope>
            <type>pom</type>
        </dependency>
    </dependencies>
</dependencyManagement>
```

Problem: Zwei Objekte sind gleich, obwohl sie
nicht gleich sein sollten

```
1 public final class Person {  
2  
3     private String firstName;  
4     private String lastName;  
5     private String jobTitle;  
6  
7     // more code like getter and setter  
8  
9     @Override  
10    public boolean equals(Object o) {  
11        if (this == o) return true;  
12        if (o == null || getClass() != o.getClass()) return false;  
13        Person person = (Person) o;  
14        return Objects.equals(firstName, person.firstName) &&  
15                Objects.equals(lastName, person.lastName) &&  
16                Objects.equals(jobTitle, person.jobTitle);  
17    }  
18  
19    @Override  
20    public int hashCode() {  
21        return Objects.hash(firstName, lastName, jobTitle);  
22    }  
23 }
```

equals() Contract

- It is *reflexive*: for any non-null reference value x , $x.equals(x)$ should return true.
- It is *symmetric*: for any non-null reference values x and y , $x.equals(y)$ should return true if and only if $y.equals(x)$ returns true.
- It is *transitive*: for any non-null reference values x , y , and z , if $x.equals(y)$ returns true and $y.equals(z)$ returns true, then $x.equals(z)$ should return true.
- It is *consistent*: for any non-null reference values x and y , multiple invocations of $x.equals(y)$ consistently return true or consistently return false, provided no information used in equals comparisons on the objects is modified.
- For any non-null reference value x , $x.equals(null)$ should return false.

Zur Erinnerung

hashCode() Contract

- *hashCode()* must return same integer consistently for the same object.
- *hashCode()* for two *a.equals(b)* object must be same, ie *a.hashCode()* is same as *b.hashCode()*.
- *hashCode()* for two *not equals()* object may not be distinct.

Zur Erinnerung

EqualsVerifier

```
1  @Test
2  void equalsContractVerySimple(){
3      Person person1 = createPerson();
4      Person person2 = createPerson();
5      person2.setJobTitle("Consultant");
6
7      assertThat(person1).isNotEqualTo(person2);
8      assertThat(person1.hashCode()).isNotEqualTo(person2.hashCode());
9  }
```

```
12  @Test
13  void equalsContractMuchBetter(){
14      EqualsVerifier.forClass(Person.class)
15          .suppress(Warning.NONFINAL_FIELDS).verify();
16  }
```



```
java.lang.AssertionError: EqualsVerifier found a problem in class Person.  
-> Mutability: equals depends on mutable field firstName.
```

For more information, go to: <http://www.jqno.nl>equalsverifier/errormessages>

```
at nl.jqno.equalsverifier.EqualsVerifierApi.verify(EqualsVerifierApi.java:305)  
at com.github.sparsick.test.tool.database.PersonTest.equalsContractMuchBetter(PersonTest.java:26)  
at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke0(Native Method)  
at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:62)  
at  
java.base/jdk.internal.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)  
at java.base/java.lang.reflect.Method.invoke(Method.java:566)  
at org.junit.platform.commons.util.ReflectionUtils.invokeMethod(ReflectionUtils.java:675)  
at org.junit.jupiter.engine.execution.MethodInvocation.proceed(MethodInvocation.java:60)  
at  
org.junit.jupiter.engine.execution.InvocationInterceptorChain$ValidatingInvocation.proceed(InvocationInterceptorChain.java:125)  
at org.junit.jupiter.engine.extension.TimeoutExtension.intercept(TimeoutExtension.java:132)  
at org.junit.jupiter.engine.extension.TimeoutExtension.interceptTestableMethod(TimeoutExtension.java:124)  
at org.junit.jupiter.engine.extension.TimeoutExtension.interceptTestMethod(TimeoutExtension.java:74)  
at  
org.junit.jupiter.engine.execution.ExecutableInvoker$ReflectiveInterceptorCall.lambda$ofVoidMethod$0(ExecutableInvoker.java:115)  
at org.junit.jupiter.engine.execution.ExecutableInvoker.lambda$invoke$0(ExecutableInvoker.java:105)  
at  
org.junit.jupiter.engine.execution.InvocationInterceptorChain$InterceptedInvocation.proceed(InvocationInterceptorChain.java:104)  
.
```

Was ist mit *toString()*?

Problem: *toString()* beinhaltet nicht alle Klassenfelder

```
1 public final class Person {  
2  
3     private String firstName;  
4     private String lastName;  
5     private String jobTitle;  
6  
7     // more code like getter, setter, hashCode and equals  
8  
9  
10    @Override  
11    public String toString() {  
12        return "Person{" +  
13                "firstName='" + firstName + '\'' +  
14                ", lastName='" + lastName + '\'' +  
15                ", jobTitle='" + jobTitle + '\'' +  
16                '}';  
17    }  
18}
```

To String Verifier

```
1  @Test
2  void toStringVerifier(){
3      ToStringVerifier.forClass(Person.class)
4          .withClassName(Style.SIMPLE_NAME)
5          .verify();
6  }
```



```
java.lang.AssertionError:  
  
Failed verification:  
com.github.sparsick.test.tool.database.Person  
  
Expected auto generated toString:  
Person{firstName='4b2b5d96-7d9f-46a3-a7ce-dd416c46706c', lastName='bb28f281-5cf4-43be-90ba-9dffaac274e6',  
jobTitle='a000c70c-1107-4a30-b9b9-5176222a4da6'}  
  
To start with class name: com.github.sparsick.test.tool.database.Person  
  
at com.jparams.verifier.tostring.ToStringVerifier.verify(ToStringVerifier.java:362)  
at com.github.sparsick.test.tool.database.PersonTest.toStringVerifier(PersonTest.java:33)  
at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke0(Native Method)  
at java.base/jdk.internal.reflect.NativeMethodAccessorImpl.invoke(NativeMethodAccessorImpl.java:62)  
at  
java.base/jdk.internal.reflect.DelegatingMethodAccessorImpl.invoke(DelegatingMethodAccessorImpl.java:43)  
at java.base/java.lang.reflect.Method.invoke(Method.java:566)  
at org.junit.platform.commons.util.ReflectionUtils.invokeMethod(ReflectionUtils.java:675)  
at org.junit.jupiter.engine.execution.MethodInvocation.proceed(MethodInvocation.java:60)  
at  
org.junit.jupiter.engine.execution.InvocationInterceptorChain$ValidatingInvocation.proceed(InvocationInterceptorChain.java:125)  
at org.junit.jupiter.engine.extension.TimeoutExtension.intercept(TimeoutExtension.java:132)  
at org.junit.jupiter.engine.extension.TimeoutExtension.interceptTestableMethod(TimeoutExtension.java:124)  
at org.junit.jupiter.engine.extension.TimeoutExtension.interceptTestMethod(TimeoutExtension.java:74)  
at  
org.junit.jupiter.engine.execution.ExecutableInvoker$ReflectiveInterceptorCall.lambda$ofVoidMethod$0(Executable
```

To String Verifier

- NameStyle
- Preset
 - Eclipse
 - IntelliJ
 - Guava
 - ApacheToStringBuilder
- Weitere Verifier (Auswahl)
 - withHashCode
 - withIgnoreFields
 - withNullField
 - withOnlyTheseFields

Problem: Wie soll ich Nebenläufigkeit testen?

Awaitility

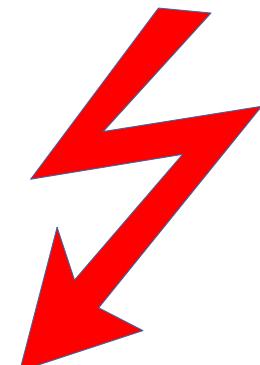


- Java DSL, um asynchrone Operationen zu synchronisieren
- Support:
 - Groovy DSL
 - Kotlin DSL
 - Scala DSL

Wichtig !

Awaitility macht nichts, um Thread-Sicherheit oder Thread-Synchronisierung zu gewährleisten.

It's your job!



Beispiel

```
@Test
void awaitilityDemo() {
    var demoUnderTest = new ConcurrencyDemo();
    demoUnderTest.addItem("Hello World");

    await().until(demoUnderTest::hasNewItem);
    assertThat(demoUnderTest.allItems()).contains("Hello World");
}
```

Weitere Möglichkeiten (Auswahl)

Abfragen von Feldern:

```
await().until( fieldIn(object).ofType(int.class), equalTo(2) );
```

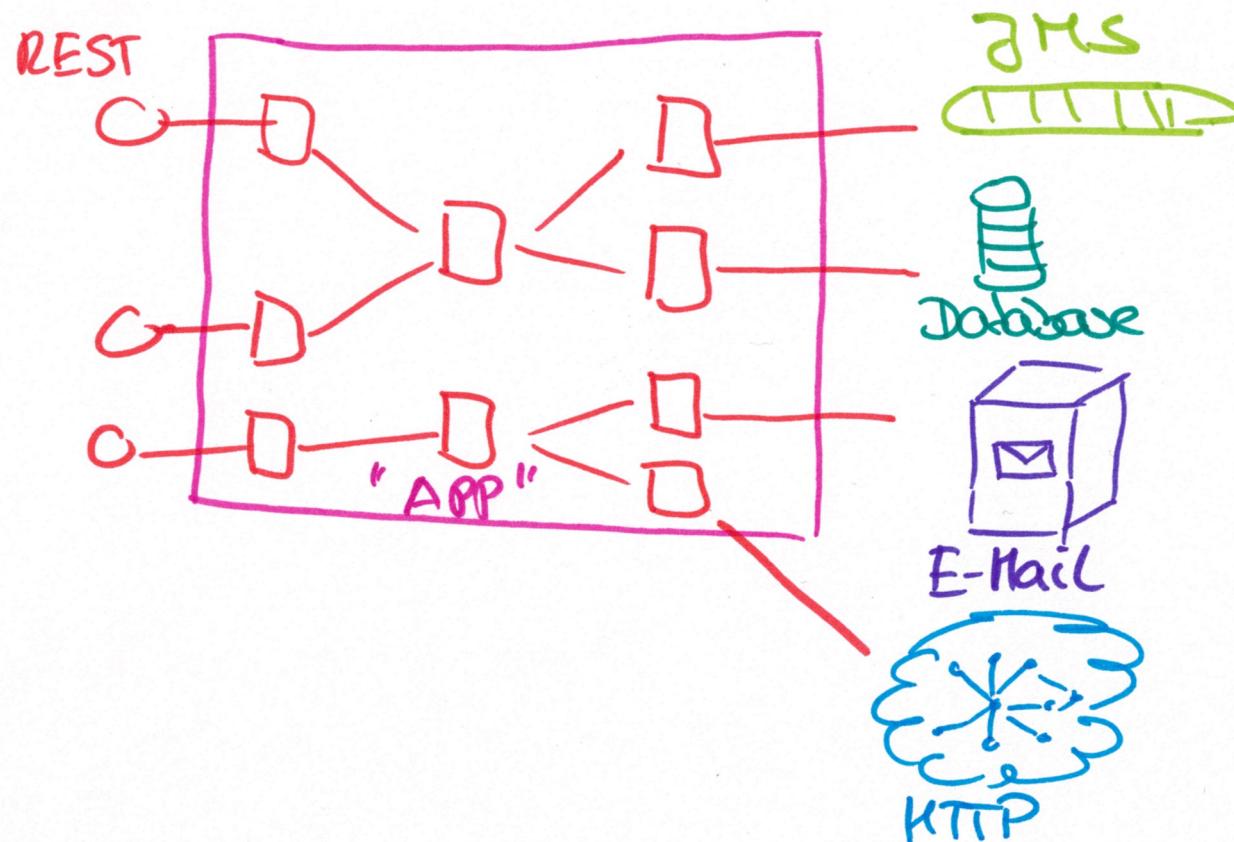
Ignorieren von Exceptions:

```
given().ignoreExceptions().await().until(() -> SocketUtils.findAvailableTcpPort(x,y));
```

Abwarten einer Mindestzeit:

```
await().atLeast(1, SECONDS).and().atMost(2, SECONDS).until(value(), equalTo(1));
```

Problem: Integrierte Tests



Problembeschreibung

- Interaktion mit Infrastruktur wird recht spät getestet
 - Feedback bei Fehlern recht spät
- Abhängig von einer bestimmten Infrastruktur
 - Manchmal auch schon beim Build (Bad smell)
 - False negative Fehlerquote recht hoch
 - Aufwändiges Setup
 - Testausführung langsam

Integration vs Integrated Tests

Integrated Tests

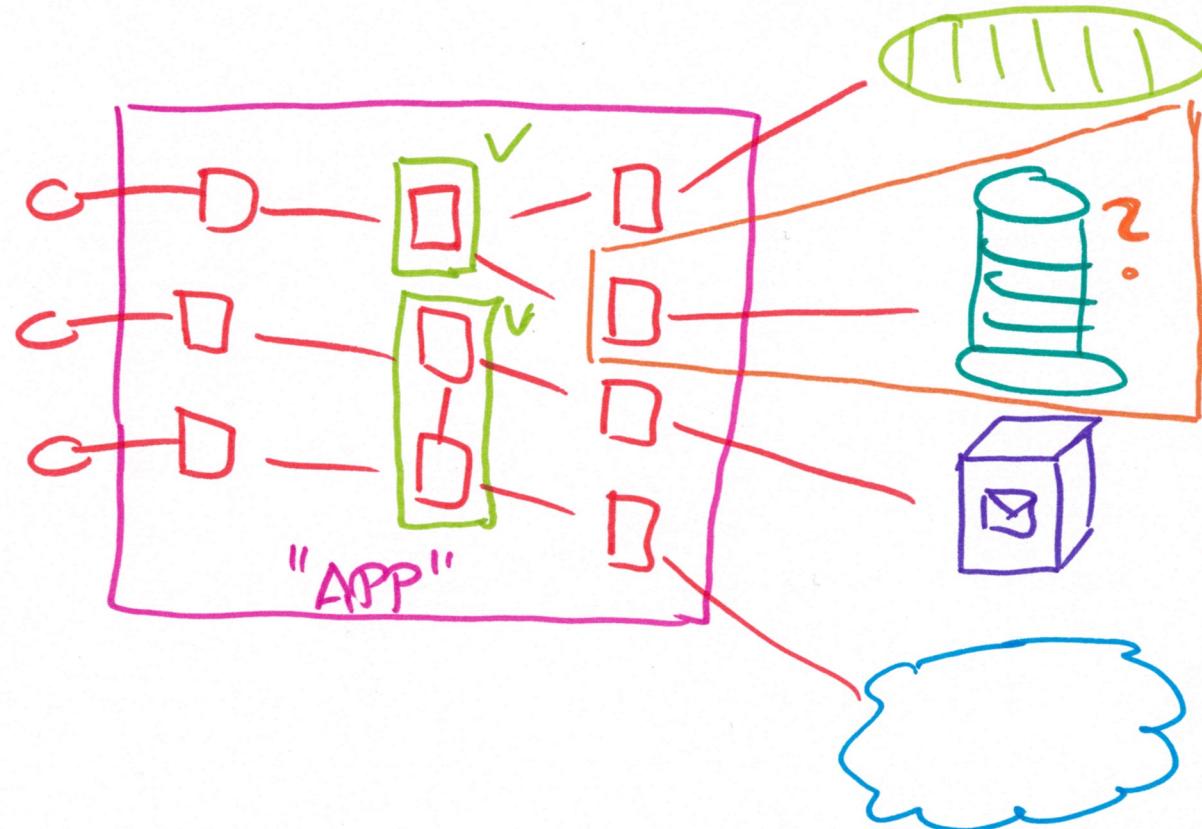
A test that will pass or fail based on the correctness of another system.

J.B.Rainsberger

Signs for having Integrated Tests:

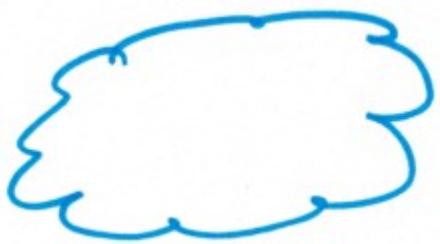
- We spin up other services in a local testing environment
- We test against other services in a shared testing environment
- Changes to your system breaks tests for other systems

from Spotify Blog Post



Anforderungen

- Build muss unabhängig von anderen Systemen sein
 - Minimierung der false negative Fehler
 - Entkopplung zwischen den Entwicklern
- Feedback bei Fehlern so schnell wie möglich
- Testausführung beschleunigen

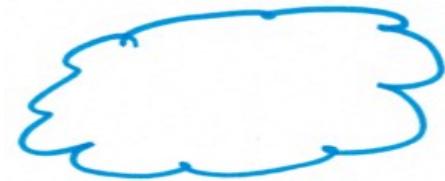


HTTP



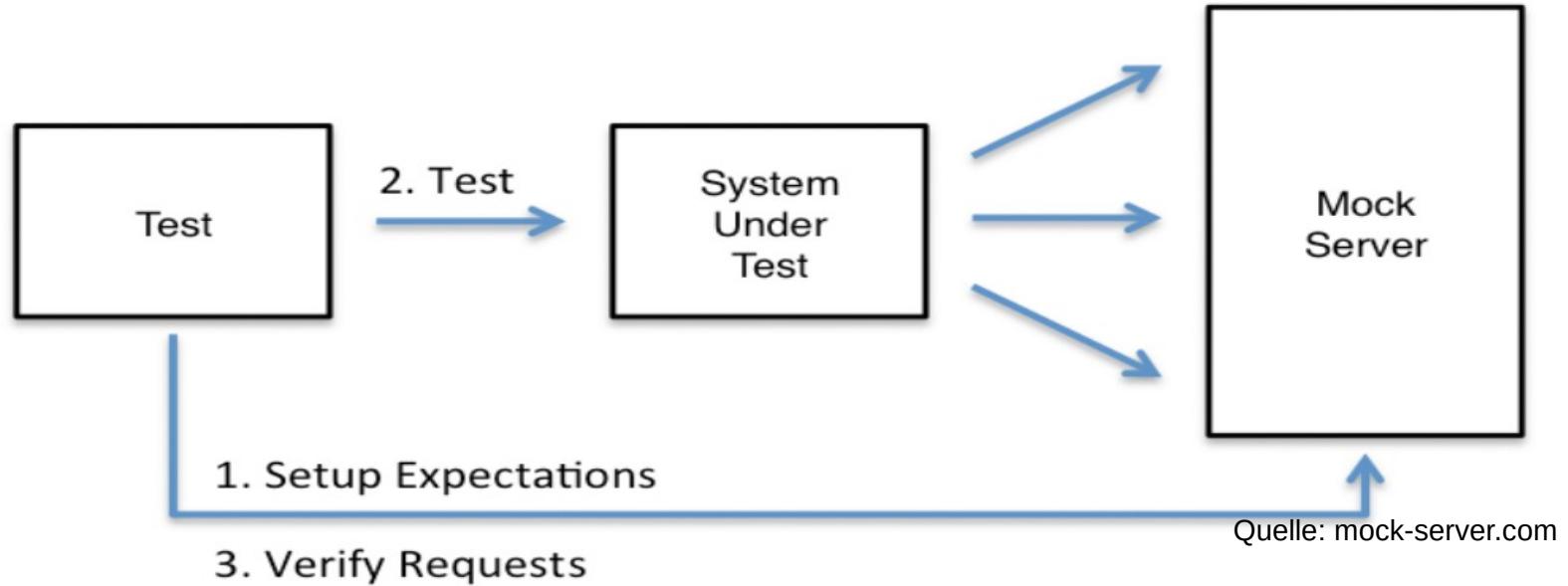
Datenbank

HTTP

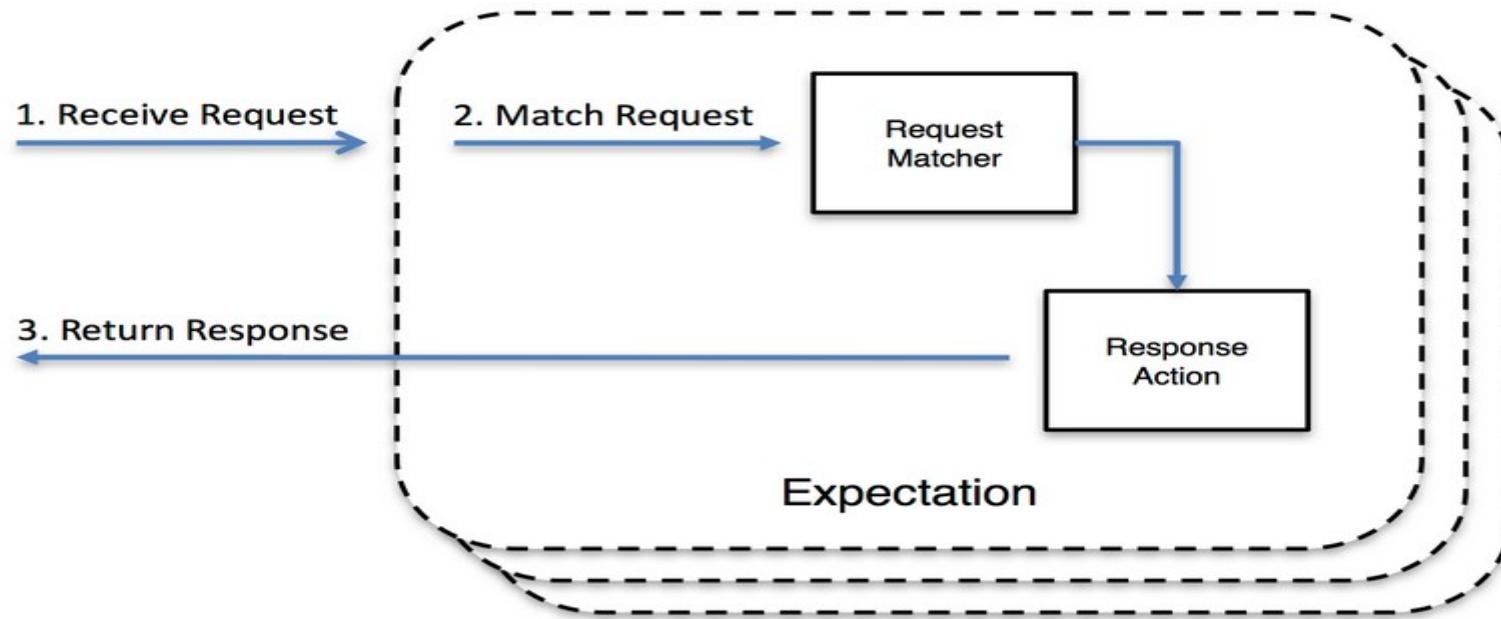


Mocking HTTP Calls

- MockServer (<http://mock-server.com/>)
- WireMock (<http://wiremock.org/>)

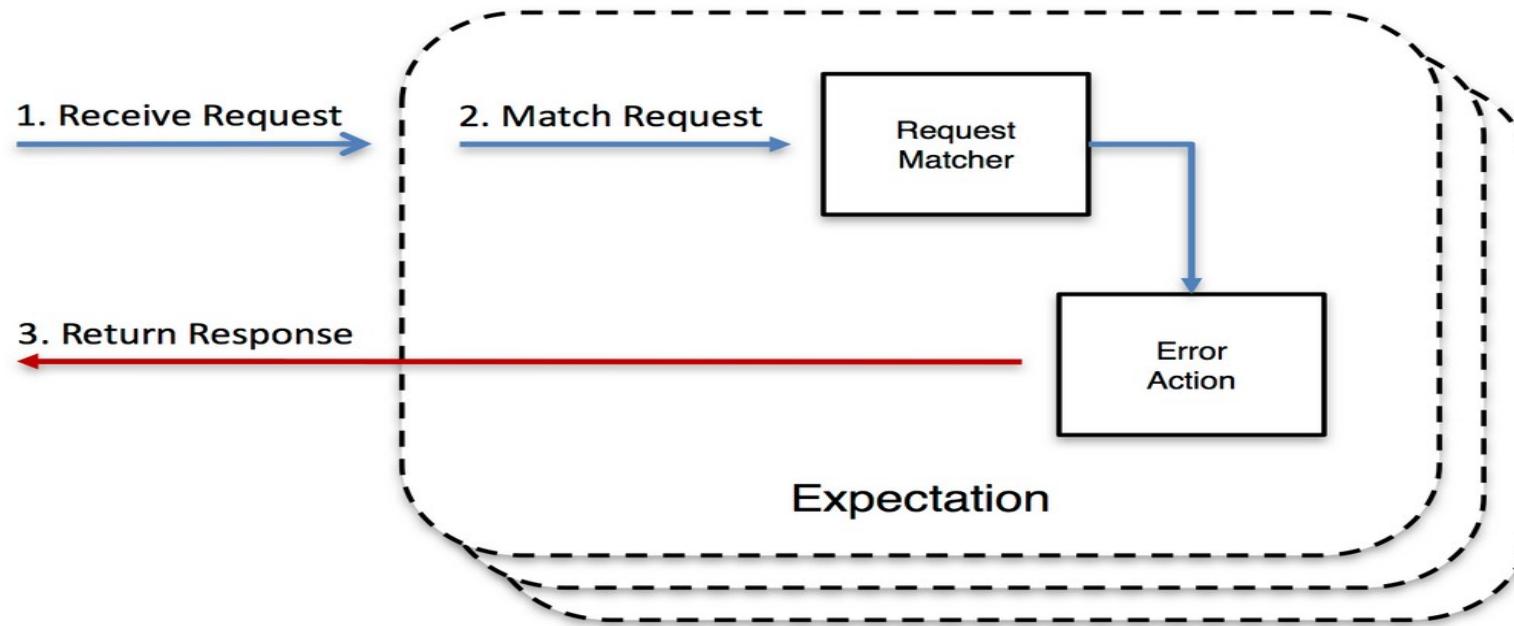


MockServer



Quelle: mock-server.com

MockServer



Quelle: mock-server.com

```
1 ▼ {
2   "count": 37,
3   "next": "https://swapi.co/api/starships/?page=2",
4   "previous": null,
5 ▼ "results": [
6 ▼   {
7     "name": "Executor",
8     "model": "Executor-class star dreadnought",
9     "manufacturer": "Kuat Drive Yards, Fondor Shipyards",
10    "cost_in_credits": "1143350000",
11    "length": "19000",
12    "max_atmosphering_speed": "n/a",
13    "crew": "279144",
14    "passengers": "38000",
15    "cargo_capacity": "2500000000",
16    "consumables": "6 years",
17    "hyperdrive_rating": "2.0",
18    "MGLT": "40",
19    "starship_class": "Star dreadnought",
20    "pilots": [],
21    "films": [
22      "https://swapi.co/api/films/2/",
23      "https://swapi.co/api/films/3/"
24    ],
25    "created": "2014-12-15T12:31:42.547000Z",
26    "edited": "2017-04-19T10:56:06.685592Z",
27    "url": "https://swapi.co/api/starships/15/"
28  },
29  ...
30 ]
```

<http://swapi.co/api/starships>

```
public class StarWarsClient {  
    private final RestTemplate restTemplate;  
    private final String baseUrl;  
  
    public StarWarsClient(String baseUrl) {  
        this.restTemplate = new RestTemplateBuilder().build();  
        try {  
            this.baseUrl = new URL(baseUrl).toString();  
        } catch (MalformedURLException e) {  
            throw new RuntimeException(e);  
        }  
    }  
  
    public List<Starship> findAllStarships() {  
        List<Starship> starships = new ArrayList<>();  
        String nextPageUrl = baseUrl + "/api/starships";  
        do {  
            String forObject = restTemplate.getForObject(nextPageUrl, String.class);  
            Map<String, Object> jsonMap = new GsonJsonParser().parseMap(forObject);  
            nextPageUrl = (String) jsonMap.get("next");  
            for (Map result : (List<Map>) jsonMap.get("results")) {  
                starships.add(Starship.from(result));  
            }  
        }  
        while (nextPageUrl != null);  
        return starships;  
    }  
}
```

```
@ExtendWith(MockServerExtension.class)
public class StarWarsClientMockserverTest {

    private MockServerClient mockServerClient;
    private StarWarsClient clientUnderTest;

    public StarWarsClientMockserverTest(MockServerClient mockServerClient) {
        this.mockServerClient = mockServerClient;
        clientUnderTest = new StarWarsClient("http://localhost:" + mockServerClient.remoteAddress().getPort());
    }

    @Test
    void findAllStarships() {
        mockServerClient
            .when(request()
                .withMethod("GET")
                .withPath("/api/starships")
            )
            .respond(response()
                .withBody(starshipTestData)
            );
        mockServerClient
            .when(request()
                .withMethod("GET")
                .withPath("/api/starships2")
            )
            .respond(response()
                .withBody(starshipTestData2)
            );
    }

    List<Starship> allStarships = clientUnderTest.findAllStarships();

    assertThat(allStarships).hasSize(11);
}
}
```

Don't mock API you don't own

Verified Fakes

Tests, die die richtige API aufrufen und verifizieren ob die
Test Doubles richtig sind

Eigene HTTP Endpoints

- Jersey → JerseyTest
- Spring MVC → MockMvc
- Framework-unabhängig
 - REST Assured (<http://rest-assured.io/>)
 - „Killer“-Feature: JsonPath, XmlPath
 - Scala Support
 - Spring MVC Support
 - Given-when-then Struktur

Rest Assured - JsonPath

```
{  
  "lotto": {  
    "lottoId": 5,  
    "winning-numbers": [2, 45, 34, 23, 7, 5, 3],  
    "winners": [{  
      "winnerId": 23,  
      "numbers": [2, 45, 34, 23, 3, 5]  
    }, {  
      "winnerId": 54,  
      "numbers": [52, 3, 12, 11, 18, 22]  
    }]  
  }  
}
```

<http://localhost:8080/lotto>

```
get("/lotto").then().body("lotto.lottoId", equalTo(5));
```

```
get("/lotto").then().body("lotto.winners.winnerId", hasItems(23, 54));
```

Quelle: Rest Assured Doc

Rest Assured - XMLPath

```
<greeting>
  <firstName>{params("firstName")}</firstName>
  <lastName>{params("lastName")}</lastName>
</greeting>
```

```
given().
when().
then().
```

```
parameters("firstName", "John", "lastName", "Doe").
post("/greetXML").
body("greeting.firstName", equalTo("John")).
body("greeting.lastName", equalTo("Doe"));
```

<http://localhost:8080/greetXML>

Quelle: Rest Assured Doc

Rest Assured – Spring MVC

```
@Controller
@RequestMapping("starwars")
public class StarWarsMovieController {

    @RequestMapping(value="movies", method = RequestMethod.GET, produces = "application/json")
    public @ResponseBody List<StarWarsMovie> findAllMovies(){
        return List.of(new StarWarsMovie("A New Hope", "George Lucas"),
                      new StarWarsMovie("The Force Awakens", "J. J. Abrams"));
    }
}
```

Rest Assured – Spring MVC

```
@RunWith(SpringRunner.class)
@WebMvcTest(StarWarsMovieController.class)
public class StarWarsMovieControllerITest {

    @Autowired
    private MockMvc mockMvc;

    @Test
    public void findAllMovies(){
        given().mockMvc(mockMvc).
        when().get("/starwars/movies").
        then().statusCode(200)
            .body("title", hasItems("A New Hope", "The Force Awakens"))
            .body("director", hasItems("George Lucas", "J. J. Abrams"));
    }

    @Test
    public void findAllMovies_plainMockMvc() throws Exception {
        mockMvc.perform(get("/starwars/movies"))
            .andExpect(status().isOk())
            .andExpect(jsonPath("[0].title").value("A New Hope"))
            .andExpect(jsonPath("[0].director").value("George Lucas"))
            .andExpect(jsonPath("[1].title").value("The Force Awakens"))
            .andExpect(jsonPath("[1].director").value("J. J. Abrams"));
    }
}
```

Unit Tests für Endpoints

```
class StarWarsMovieControllerTest {

    @Test
    void findAllMovies(){
        StarWarsMovieController controllerUnderTest = new StarWarsMovieController();
        List<StarWarsMovie> movies = controllerUnderTest.findAllMovies();

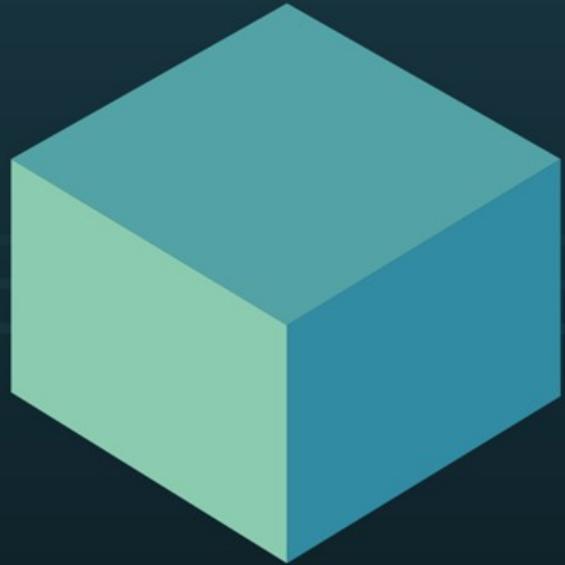
        assertThat(movies)
            .hasSize(2)
            .extracting("director")
            .containsExactlyInAnyOrder( "George Lucas", "J. J. Abrams" );
    }
}
```

Datenbanken



Datenbanken

- Embedded Datenbanken
 - H2, Derby
 - Nicht Produktionsnah
 - Nicht alles testbar
- Standalone Datenbanken
 - Abhängigkeit zur bestimmten Infrastruktur
- Shared Datenbanken
 - Abhängigkeiten zwischen Entwickler
 - Hohe false negative Fehlerrate



TESTCONTAINERS

```
@Testcontainers
class PersonRepositoryJUnit5Test {

    @Container
    private PostgreSQLContainer postgres = new PostgreSQLContainer();

    private PersonRepository repositoryUnderTest;

    @BeforeEach
    void setup(){
        HikariConfig hikariConfig = new HikariConfig();
        hikariConfig.setJdbcUrl(postgres.getJdbcUrl());
        hikariConfig.setUsername(postgres.getUsername());
        hikariConfig.setPassword(postgres.getPassword());

        HikariDataSource ds = new HikariDataSource(hikariConfig);
        Flyway flyway = Flyway.configure().dataSource(ds).load();
        flyway.migrate();

        repositoryUnderTest = new PersonRepository(ds);
    }

    @Test
    void saveAndFindAllPerson() {
        Person person = new Person();
        person.setFirstName("firstName");
        person.setLastName("lastName");
        person.setJobTitle("jobTitle");

        repositoryUnderTest.save(person);

        List<Person> persons = repositoryUnderTest.findAllPersons();
        assertThat(persons).hasSize(1).contains(person);
    }
}
```

```
@Testcontainers
class DbMigrationJUnit5Test {

    @Container
    private MySQLContainer mysqlDb = new MySQLContainer();

    @Test
    void testDbMigrationFromTheScratch(){
        Flyway flyway = Flyway.configure()
            .dataSource(mysqlDb.getJdbcUrl(),
                       mysqlDb.getUsername(),
                       mysqlDb.getPassword()).load();

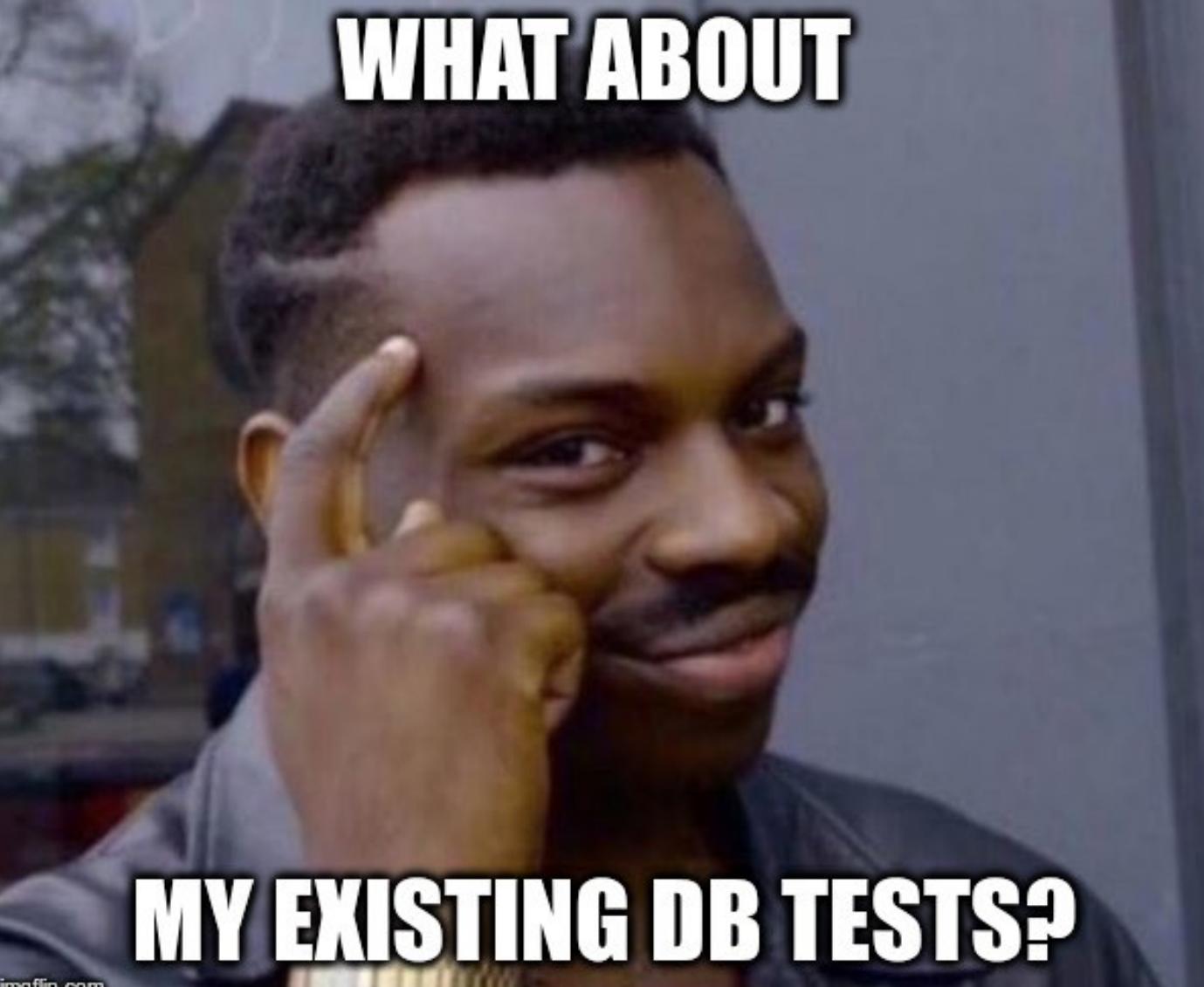
        flyway.migrate();
    }
}
```

TESTS

```
-----  
Running db.migration.DbMigrationITest  
INFO - RegistryClientProviderStrategy - Found docker client settings from environment  
INFO - DockerClientProviderStrategy - Found Docker environment with Environment variables, system properties and defaults. Resolved:  
  dockerHost=unix:///var/run/docker.sock  
  apiVersion='{UNKNOWN_VERSION}'  
  registryUrl='https://index.docker.io/v1/'  
  registryUsername='sparsick'  
  registryPassword='null'  
  registryEmail='null'  
  dockerConfig='DefaultDockerClientConfig[dockerHost=unix:///var/run/docker.sock, registryUsername=sparsick, registryPassword=<null>, registryEmail=<null>]'  
INFO - DockerClientFactory      - Docker host IP address is localhost  
INFO - DockerClientFactory      - Connected to docker:  
  Server Version: 17.05.0-ce  
  API Version: 1.29  
  Operating System: Linux Mint 18.2  
  Total Memory: 19511 MB  
    i Checking the system...  
    ✓ Docker version is newer than 1.6.0  
    ✓ Docker environment has more than 2GB free  
    ✓ File should be mountable  
    ✓ Exposed port is accessible  
INFO - [mysql:latest]           - Creating container for image: mysql:latest  
INFO - [mysql:latest]           - Starting container with ID: 2668be66c2631e49b5bcb4e180665d223525ec896ea78034326076d5f9063d53  
INFO - [mysql:latest]           - Container mysql:latest is starting: 2668be66c2631e49b5bcb4e180665d223525ec896ea78034326076d5f9063d53  
INFO - [mysql:latest]           - Waiting for database connection to become available at jdbc:mysql://localhost:32769/test using query 'SELECT  
INFO - [mysql:latest]           - Obtained a connection to container (jdbc:mysql://localhost:32769/test)  
INFO - [mysql:latest]           - Container mysql:latest started  
INFO - VersionPrinter          - Flyway 4.0.3 by Boxfuse  
INFO - DbSupportFactory         - Database: jdbc:mysql://localhost:32769/test (MySQL 5.7)  
INFO - DbValidate               - Successfully validated 2 migrations (execution time 00:00.011s)  
INFO - MetaDataTableImpl        - Creating Metadata table: `test`.`schema_version`  
INFO - DbMigrate                - Current version of schema `test`: <> Empty Schema <>  
INFO - DbMigrate                - Migrating schema `test` to version 1.0.0 - create person table  
INFO - DbMigrate                - Migrating schema `test` to version 2.0.0 - add column job title  
INFO - DbMigrate                - Successfully applied 2 migrations to schema `test` (execution time 00:00.133s).  
Tests run: 1, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 13.9 sec
```

Testcontainers

- Temporary database containers - spezielle MySQL, PostgreSQL, Oracle XE und Virtuoso container
- Webdriver containers - Dockerized Chrome oder Firefox browser für Selenium/Webdriver Operationen mit automatischer Videoaufnahme
- Weitere spezifische Container – Elasticsearch, Kafka, Apache Pulsar, Mockserver, Toxiproxy, Nginx, Hashicorp Vault
- Generic containers – irgendein Docker Container
- Docker compose – Wiederverwendung von Docker Compose YAML Datei
- Dockerfile containers – Container direkt von einem Dockerfile



WHAT ABOUT

MY EXISTING DB TESTS?

Container Via JDBC URL

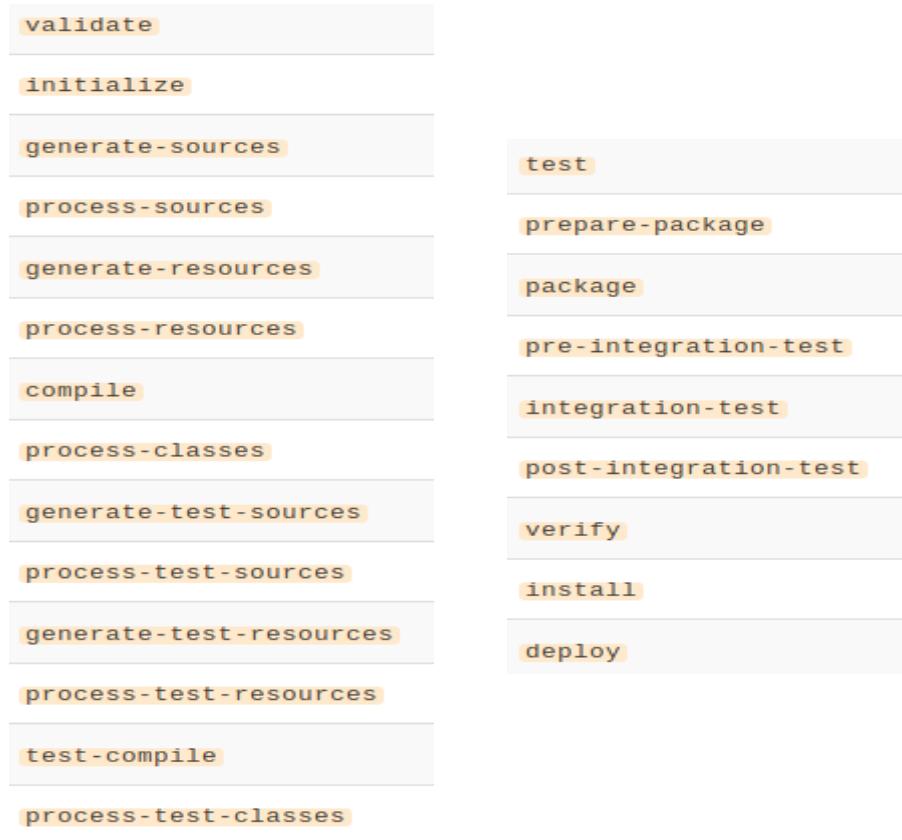
```
public class PersonRepositoryJdbcUrlTestContainerTest {  
    private PersonRepository repositoryUnderTest;  
    private Flyway flyway;  
  
    @BeforeEach  
    void setup(){  
        HikariConfig hikariConfig = new HikariConfig();  
        hikariConfig.setJdbcUrl("jdbc:tc:postgresql:9.6.8:///persondb");  
        hikariConfig.setUsername("postgres");  
        hikariConfig.setPassword("");  
  
        DataSource ds = new HikariDataSource(hikariConfig);  
        flyway = Flyway.configure().dataSource(ds).load();  
        flyway.migrate();  
  
        repositoryUnderTest = new PersonRepository(ds);  
    }  
  
    @AfterEach  
    void cleanUp(){  
        flyway.clean();  
    }  
}
```

Docker Maven Plugin (DMP)

- fabric8io/docker-maven-plugin (<http://dmp.fabric8.io>)
- Kann Docker Image bauen
- Aber auch Container starten und stoppen

Maven Phase: Integration-Test

- Ausgangspunkt:
 - Es gibt Integrationstests gegen embedded oder standalone Datenbank
- Improvement:
 - DMP startet Container vor den Tests (*pre-integration-test*)
 - DMP stoppt Contianer nach den Tests (*post-integration-test*)



Fazit

Integration Tests Mockserver, Wiremock, REST Assured Greenmail Testcontainers	equals, hashCode, toString EqualsVerifier, ToStringVerifier	Concurrency Awaitility
Gut lesbare Assertions AssertJ, AssertJ-DB, JUnit5 Group Assertion		
Testdaten generatedata.com JavaFaker ObjectMother, TestDataBuilder	Parametrisierte Tests JUnit5, Spock	Tests, die nur unter bestimmten Bedingungen laufen JUnit5 ConditionsTest

Fragen?

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@SandraParsick

<https://github.com/sparsick/test-tool-talk>

Literatur

- <https://www.martinfowler.com/bliki/ObjectMother.html>
- <http://natpryce.com/articles/000714.html>
- <http://coding-is-like-cooking.info/2018/04/pre-tested-integration-back-to-the-basis-of-ci/>
- <http://blog.thecodewhisperer.com/permalink/integrated-tests-are-a-scam>
- <http://blog.thecodewhisperer.com/permalink/clearing-up-the-integrated-tests-scam>
- https://bee42.com/de/blog/The_dark_age_of_container_testing/

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- <https://martinfowler.com/bliki/IntegrationTest.html>
- <https://codewithoutrules.com/2016/07/31/verified-fakes/>